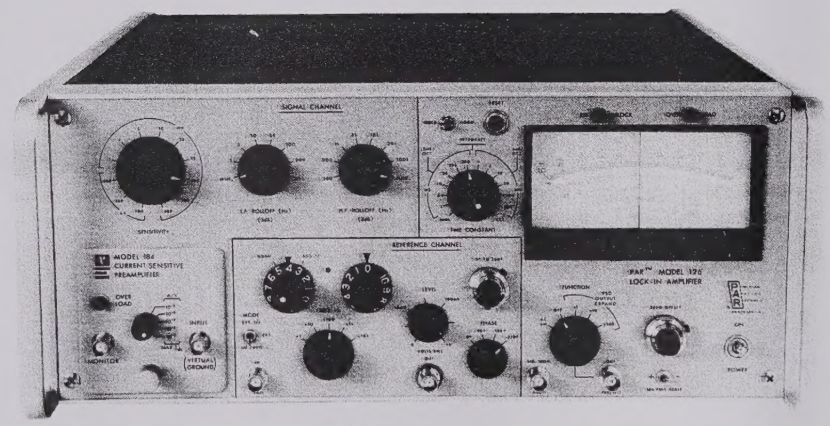
MODEL 126
LOCK-IN
AMPLIFIER

SEE SAFETY NOTICE
THAT PRECEDES SECTION I
BEFORE OPERATING INSTRUMENT



OPERATING AND SERVICE MANUAL

EG&G
PRINCETON APPLIED RESEARCH

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MODEL 126
LOCK-IN AMPLIFIER

OPERATING AND SERVICE MANUAL

EG&G PRINCETON APPLIED RESEARCH

MDL 126; 10/79-GMI

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SHOULD YOUR EQUIPMENT REQUIRE SERVICE

A. Contact the factory (609/452-2111) or your local factory representative to discuss the problem. In many cases it will be possible to expedite servicing by localizing the problem to a particular plug-in circuit board.

B. If it is necessary to send any equipment back to the factory, we need the following information.

(1) Model number and serial number.

(2) Your name (instrument user).

(3) Your address.

(4) Address to which instrument should be returned.

(5) Your telephone number and extension.

(6) Symptoms (in detail, including control settings).

(7) Your purchase order number for repair charges (does not apply to repairs in warranty).

(8) Shipping instructions (if you wish to authorize shipment by any method other than normal surface transportation).

C. U.S. CUSTOMERS—Ship the equipment being returned to:

EG&G PRINCETON APPLIED RESEARCH
7 Roszel Road
(Off Alexander Road, East of Route 1)
Princeton, New Jersey

D. CUSTOMERS OUTSIDE OF U.S.A.—To avoid delay in customs clearance of equipment being returned, please contact the factory or the nearest factory distributor for complete shipping information.

E. Address correspondence to:

EG&G PRINCETON APPLIED RESEARCH
P. O. Box 2565
Princeton, NJ 08540

Phone: 609/452-2111
TELEX: 84 3409

WARRANTY

EG&G PRINCETON APPLIED RESEARCH warrants each instrument of its manufacture to be free from defects in material and workmanship. Obligations under this Warranty shall be limited to replacing, repairing or giving credit for the purchase price, at our option, of any instrument returned, freight prepaid, to our factory within ONE year of delivery to the original purchaser, provided prior authorization for such return has been given by our authorized representative.

This Warranty shall not apply to any instrument which our inspection shall disclose to our satisfaction, has become defective or unworkable due to abuse, mishandling, misuse, accident, alteration, negligence, improper installation or other causes beyond our control. Instruments manufactured by others, and included in or supplied with our equipment, are not covered by this Warranty but carry the original manufacturer's warranty which is extended to our customers and may be more restrictive. Certain subassemblies, accessories or components may be specifically excluded from this Warranty, in which case such exclusions are listed in the Instruction Manual supplied with each instrument.

We reserve the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

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SAFETY NOTICE
(READ BEFORE OPERATING INSTRUMENT)

INTRODUCTION

The Model 126 to which these instructions apply has been supplied in a safe condition. This manual contains some information and warnings that have to be followed by the user to ensure safe operation and to retain the apparatus in a safe condition. The described apparatus has been designed for indoor use.

INSPECTION

Newly received apparatus should be inspected for shipping damage. If any is noted, notify EG&G PARC and file a claim with the carrier. Be sure to save the shipping container for inspection by the carrier.

WARNING!

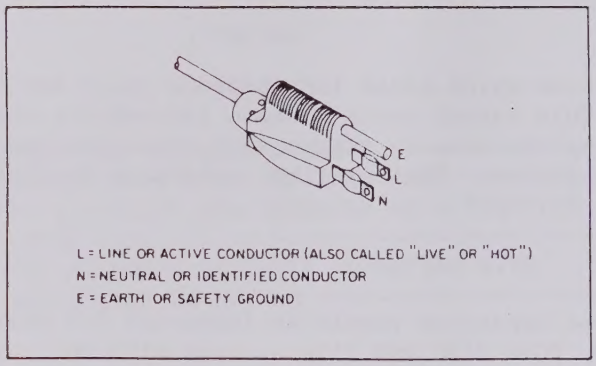
THE PROTECTIVE GROUNDING COULD BE RENDERED INEFFECTIVE IN DAMAGED APPARATUS. DAMAGED APPARATUS SHOULD NOT BE OPERATED UNTIL ITS SAFETY HAS BEEN VERIFIED BY QUALIFIED SERVICE PERSONNEL. DAMAGED APPARATUS WAITING FOR SAFETY VERIFICATION SHOULD BE TAGGED TO INDICATE TO A POTENTIAL USER THAT IT MAY BE UNSAFE AND THAT IT SHOULD NOT BE OPERATED.

SAFETY MECHANISM

As defined in IEC Publication 348 (Safety Requirements for Electronic Measuring Apparatus), this is Class I Apparatus, that is, this apparatus depends on connection to a protective conductor to earth ground for equipment and operator safety. Before any other connection is made to the apparatus, the protective earth terminal shall be connected to a protective conductor. The protective connection is made via the earth ground prong of the power cord plug. The power cord plug shall only be inserted in a socket outlet provided with the required earth ground contact. The protective action must not be negated by the use of an extension cord without a protective conductor, by use of an "adapter" that doesn't maintain earth ground continuity, or by any other means.

WARNING!

ANY INTERRUPTION OF THE PROTECTIVE CONDUCTOR INSIDE OR OUTSIDE THE APPARATUS OR DISCONNECTION OF THE PROTECTIVE EARTH TERMINAL MAY MAKE THE APPARATUS DANGEROUS. INTENTIONAL INTERRUPTION IS PROHIBITED.



POWER CORD PLUG

WARNING!

IF IT IS NECESSARY TO REPLACE THE POWER CORD OR THE POWER CORD PLUG, THE REPLACEMENT CORD OR PLUG MUST HAVE THE SAME POLARITY AS THE ORIGINAL. OTHERWISE A SAFETY HAZARD FROM ELECTRICAL SHOCK, WHICH COULD RESULT IN PERSONAL INJURY OR DEATH, MIGHT EXIST.

POWER VOLTAGE SELECTION

Before plugging in the power cord, make sure that the equipment is set to the voltage of the ac power supply. A detailed discussion of how to check and, if necessary, change the power voltage setting, follows.

The line voltage range is selected by means of a switch located on the rear panel. FOR SAFETY, UNPLUG THE POWER CORD WHEN CHECKING THE LINE VOLTAGE SETTING OR WHEN CHECKING THE LINE FUSE. THE FUSE SHOULD ONLY BE CHECKED OR CHANGED BY QUALIFIED SERVICE PERSONNEL WHO ARE AWARE OF THE HAZARDS INVOLVED. Depending on the switch position, either "115" or "230" (both are printed on the switch) will be visible to the viewer. For operation from a line voltage in the range of 100 V ac to 130 V ac, 50-60 Hz, "115" should show. For operation from a line voltage in the range of 200 V ac to 260 V ac, 50-60 Hz, "230" should show.

The power fuse is located on the rear panel. This fuse should be a BUSSMAN type MDL slow-blow fuse rated at 1/2 A for operation from a line voltage of nominally 115 V. For operation from a line voltage of nominally 230 V, the fuse should be rated at 1/4 A. The voltage rating in both cases should be 250 V.

WARNING!

TO AVOID THE POSSIBILITY OF A SAFETY HAZARD FROM ELECTRICAL SHOCK WHICH COULD RESULT IN INJURY OR DEATH, DISCONNECT THE POWER CORD BEFORE REMOVING OR INSTALLING ANY FUSE.

DEFECTS AND ABNORMAL STRESSES

Whenever it is likely that the protection provided by the connection to earth ground has been impaired, the apparatus shall be made inoperative and secured against any unintended operation. The protection is likely to be impaired if, for example, the apparatus:

(1) Shows visible damage,

(2) Fails to perform as expected,

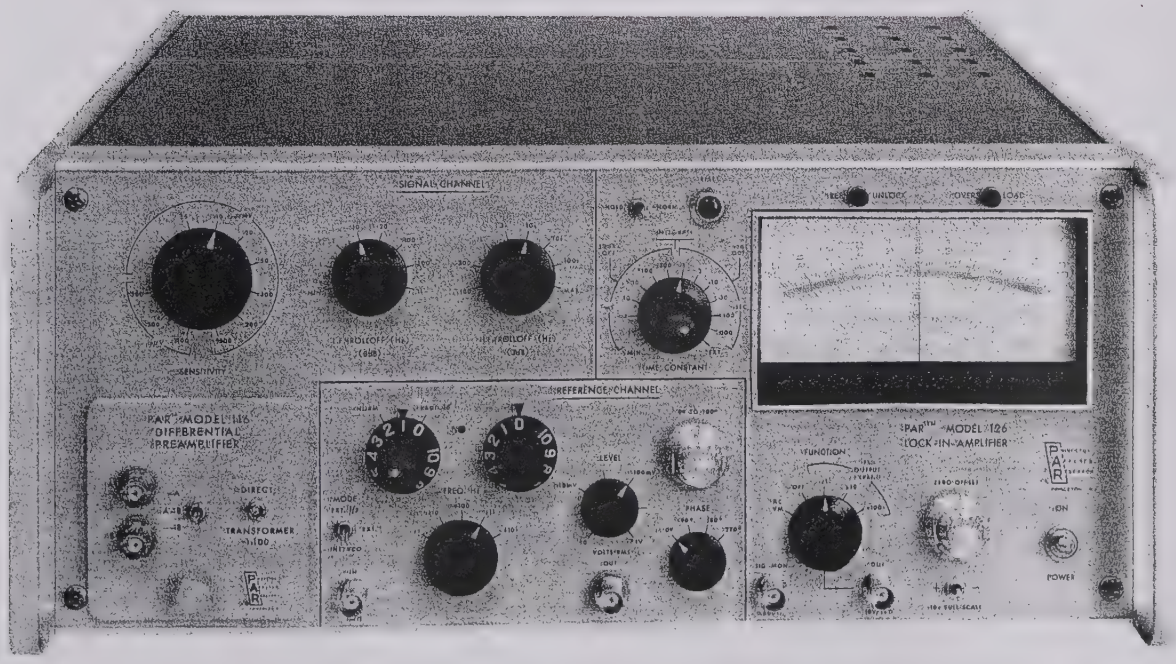
(3) Has been subjected to prolonged storage under unfavorable conditions,

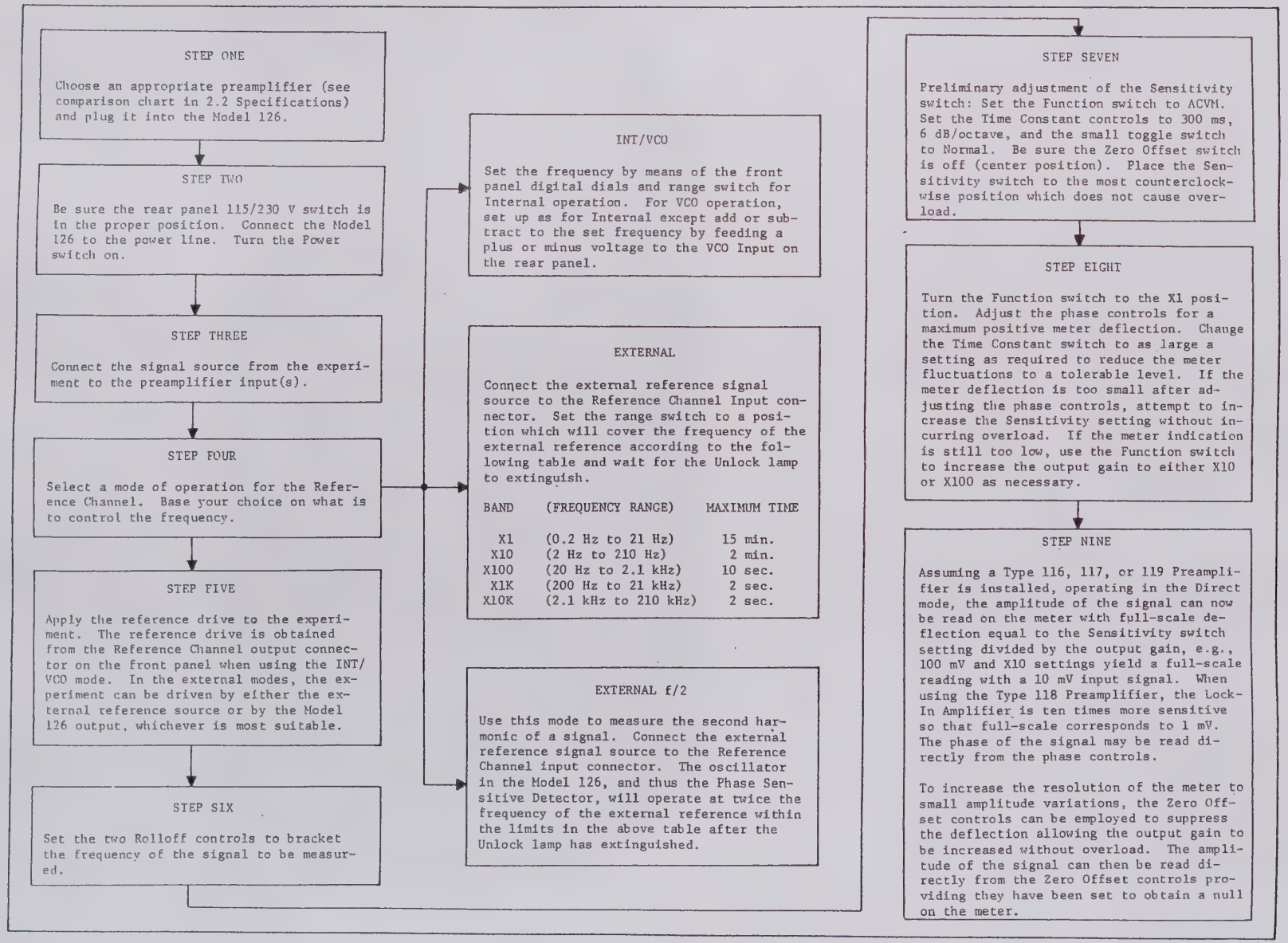
(4) Has been subjected to severe transport stresses.

SECTION I
CONDENSED OPERATING INSTRUCTIONS

The chart on the following page is provided to assist in placing the Model 126 Lock-In Amplifier into operation as quickly as possible. Since elaboration of many operating considerations have been foregone here, it is advisable to read Section IV, the complete operating instructions, for detailed information pertaining to elimination of ground loops, typical phase accuracy, and other subtle characteristics which may be of importance in a particular application. After a thorough study of Section IV, this guide will serve as a "refresher" for future reference.

The chart is based on operation of the Model 126 as a Lock-In Amplifier where the signal to be measured from an experiment must be made to appear at a reference frequency (either internally or externally generated). Operation as an ACVM, an ac signal amplifier, or as a laboratory type oscillator may be inferred from the appropriate blocks of the chart.




STEP ONE
Choose an appropriate preamplifier (see comparison chart in 2.2 Specifications) and plug it into the Model 126.
STEP TWO
Be sure the rear panel 115/230 V switch is in the proper position. Connect the Model 126 to the power line. Turn the Power switch on.
STEP THREE
Connect the signal source from the experiment to the preamplifier input(s).
STEP FOUR
Select a mode of operation for the Reference Channel. Base your choice on what is to control the frequency.
STEP FIVE
Apply the reference drive to the experiment. The reference drive is obtained from the Reference Channel output connector on the front panel when using the INT/VCO mode. In the external modes, the experiment can be driven by either the external reference source or by the Model 126 output, whichever is most suitable.
STEP SIX
Set the two Rolloff controls to bracket the frequency of the signal to be measured.
INT/VCO
Set the frequency by means of the front panel digital dials and range switch for Internal operation. For VCO operation, set up as for Internal except add or subtract to the set frequency by feeding a plus or minus voltage to the VCO Input on the rear panel.
EXTERNAL
Connect the external reference signal source to the Reference Channel Input connector. Set the range switch to a position which will cover the frequency of the external reference according to the following table and wait for the Unlock lamp to extinguish.
BAND (FREQUENCY RANGE) MAXIMUM TIME
X1 (0.2 Hz to 21 Hz) 15 min.
X10 (2 Hz to 210 Hz) 2 min.
X100 (20 Hz to 2.1 kHz) 10 sec.
X1K (200 Hz to 21 kHz) 2 sec.
X10K (2.1 kHz to 210 kHz) 2 sec.
EXTERNAL f/2
Use this mode to measure the second harmonic of a signal. Connect the external reference signal source to the Reference Channel input connector. The oscillator in the Model 126, and thus the Phase Sensitive Detector, will operate at twice the frequency of the external reference within the limits in the above table after the Unlock lamp has extinguished.
STEP SEVEN
Preliminary adjustment of the Sensitivity switch: Set the Function switch to ACVM. Set the Time Constant controls to 300 ms, 6 dB/octave, and the small toggle switch to Normal. Be sure the Zero Offset switch is off (center position). Place the Sensitivity switch to the most counterclockwise position which does not cause overload.
STEP EIGHT
Turn the Function switch to the X1 position. Adjust the phase controls for a maximum positive meter deflection. Change the Time Constant switch to as large a setting as required to reduce the meter fluctuations to a tolerable level. If the meter deflection is too small after adjusting the phase controls, attempt to increase the Sensitivity setting without incurring overload. If the meter indication is still too low, use the Function switch to increase the output gain to either X10 or X100 as necessary.
STEP NINE
Assuming a Type 116, 117, or 119 Preamplifier is installed, operating in the Direct mode, the amplitude of the signal can now be read on the meter with full-scale deflection equal to the Sensitivity switch setting divided by the output gain, e.g., 100 mV and X10 settings yield a full-scale reading with a 10 mV input signal. When using the Type 118 Preamplifier, the Lock-In Amplifier is ten times more sensitive so that full-scale corresponds to 1 mV. The phase of the signal may be read directly from the phase controls.
To increase the resolution of the meter to small amplitude variations, the Zero Offset controls can be employed to suppress the deflection allowing the output gain to be increased without overload. The amplitude of the signal can then be read directly from the Zero Offset controls providing they have been set to obtain a null on the meter.

CONDENSED OPERATING INSTRUCTIONS

SECTION II
CHARACTERISTICS

2.1 INTRODUCTION

The PARC Model 126 Lock-In Amplifier is the basis of a high-quality system for the precision measurement of signals contaminated by noise, power line interference, frequency drift, etc. The measurement is accomplished by means of an extremely narrow bandwidth phase sensitive detector which has its center frequency locked (referenced) to the frequency of the signal to be measured. This results in considerable improvement of the signal to noise ratio, permitting accurate amplitude and phase measurements.

A few of the outstanding characteristics include a series of plug-in preamplifiers providing optimum low noise figure for practically any range of signal frequency and source resistance. To compliment the standard line of plug-in preamplifiers, the Model 184 Photometric Preamplifier has a virtual ground input which connects directly and efficiently to photodetector outputs.

The succeeding signal amplifier in the Model 126 has independently adjustable high and low frequency rolloffs providing a means of rejecting a great deal of noise before phase sensitive detection. The band of frequencies which do enter the phase sensitive detector is converted to sum and difference frequencies with respect to the reference. A selectable single or double section low pass filter rejects all frequency components except the dc component due to a signal present at the reference frequency. Thus noise or other interference is eliminated, leaving only a dc voltage proportional to the signal. Calibrated phase controls indicate the phase of the incoming signal while the amplitude is displayed on a standard panel meter.

Certain design features have been incorporated to facilitate practical applications. The gain of the ac signal amplifiers before the detector and the gain of the dc amplifiers after the detector can be separately determined to obtain the greatest degree of output stability for a given incoming signal-to-noise ratio. The reference circuitry, in addition to operating as a tracking oscillator locked to either the external frequency or twice the external frequency, can also function as a VCO or as a standard laboratory oscillator with its own digital frequency dials. It is possible to operate over certain frequency ranges of 100 to 1 without touching a single control, including phase. The output filter can be switched to a true integrator mode with hold and reset capabilities.

A wide selection of accessories enhances the versatility of the Model 126. A two-phase accessory, the Model 127, enables simultaneous measurement of both in-phase and quadrature components while the Model 126 independently detects at any selected third phase or operates as a standard ac voltmeter. Other ancillary equipment includes light choppers, photomultiplier tube housings, teletype, and computer interface modules.

2.2 SPECIFICATIONS

GENERAL

FREQUENCY RANGE: 0.2 Hz to 210 kHz.

SENSITIVITY: 18 full-scale ranges in a 1-2-5 sequence combining both the Sensitivity control and Output Gain control ranges. Actual full-scale voltages are determined by the choice of preamplifier. Refer to the preamplifier chart for detailed information.

AUXILIARY POWER OUTPUT: Regulated ±24 V at 150 mA capability is available at a rear panel connector.

SIGNAL CHANNEL

PREAMPLIFIERS:

SPECIFICATION		Model 116	Model 117	Model 118	Model 119
Input Z		Selected by front panel switch: Direct: 100 meg. SE/DE Transformer[a]: Low Z SE/DE	100 megohms SE/DE	>10 kilohms SE/DE	Selected by front panel switch: Direct: 100 meg. SE/DE Transformer: Low Z SE/DE
Bandwidth		Direct: 0.2 Hz – 210 kHz Transformer[b]: 1.5 Hz – 10 kHz	0.2 Hz – 210 kHz	0.2 Hz – 210 kHz	Direct: 0.2 Hz – 210 kHz Transformer[b]: 1 kHz – 210 kHz
Noise Figure (1 dB Contour)	R_s	Direct: 4 kilohms – 20 megohms Transformer: 15 ohms – 100 ohms	4 kilohms – 20 megohms	200 ohms – 2.5 kilohms	Direct: 4 kilohms – 20 megohms Transformer: 1–10 ohms
	f	Direct: 1 Hz – 210 kHz Transformer: 20 Hz – 10 kHz	1 Hz – 210 kHz	500 Hz – 210 kHz	Direct: 1 Hz – 210 kHz Transformer: 1.5 kHz – 150 kHz
Common Mode Rejection Ratio		Direct: 120 dB at 60 Hz Transformer: 140 dB at 60 Hz	120 dB at 60 Hz	110 dB at 60 Hz	Direct: 120 dB at 60 Hz Transformer: 120 dB at 60 Hz
Full Scale Sensitivity		Direct: 1 μV Transformer: 10 nV	1 μV	100 nV	Direct: 1 μV Transformer: 10 nV
Maximum Input Voltage		Direct: ±200 Vdc Transformer: ±200 Vdc [c]	±200 Vdc	±5 V	Direct: ±200 Vdc Transformer: ±200 Vdc [c]

NOTES: a. Input Z is complex but approaches 0.25 H at low frequencies. May be wired for 1:50 to 1:350 turns ratio. Standard is 1:100.

b. Varies with source impedance.

c. Common mode only.

Table II-1. PREAMPLIFIER COMPARISON CHART

BANDWIDTH: Dynamic range of the Lock-In Amplifier is increased by limiting the bandwidth of the signal channel. Independent low and high frequency rolloff controls (6 dB/octave) set the -3 dB bandwidth. The range of the Low Frequency Rolloff is 1 Hz to 1 kHz in a 1-3-10 sequence plus MIN. The High Frequency Rolloff covers a range of 100 Hz to 100 kHz in a 1-3-10 sequence plus MAX. A relatively narrow passband (Q=½) can be obtained by setting both controls to the same frequency. When operated with maximum bandwidth, response is flat within ±1% from 10 Hz to 110 kHz, ±2% from 110 kHz to 210 kHz, and +0, -30% below 10 Hz.

SIGNAL MONITOR CONNECTOR: Allows monitoring of signal just ahead of demodulation. 100 mV rms sine wave corresponds to full-scale in X1 setting of the Function (Output Gain) switch, 10 mV in X10, and 1 mV in X100. Output impedance is 600 ohms.

Line frequency pickup due to internal power supply is less than 20 nV rms (referred to the Direct inputs of a Type 116 Preamplifier).

REFERENCE CHANNEL

OUTPUT: Sine wave at the reference oscillator frequency. Amplitude is continuously adjustable from 0 to 1 V rms by means of the Level control. Total harmonic distortion is less than 2%. An optional power amplifier is available which increases the maximum output level to 10 V rms (adjustable from 0 V to 10 V) and fixes the output impedance at 600 ohms.

OPERATING MODES:

INT/VCO: Frequency of the internal reference oscillator is set by means of the front panel digital dials and/or the rear panel VCO Input control voltage. Frequency dial accuracy is ±2% or 0.05 Hz, whichever is greater. VCO control voltage of 0 to ±10 V corresponds to the full frequency range of the set band. VCO input impedance is 10 kilohms.

EXTERNAL: The internal reference oscillator will lock in both frequency and phase to virtually any externally generated signal crossing its mean only twice each cycle. Minimum time required on either side of the mean is 100 ns. Amplitude excursion must be at least 50 mV on each side of the mean. Input impedance is 1 megohm.

Once locked-on, the reference oscillator will track the external signal over a frequency range of 100:1 within the range of the set band of frequencies. Maximum frequency acquisition (lock-on) times for each frequency band are given in the following table:

BAND	(FREQUENCY RANGE)	MAXIMUM TIME*
X1	(0.2 Hz to 21 Hz)	15 min.
X10	(2 Hz to 210 Hz)	2 min.
X100	(20 Hz to 2.1 kHz)	10 sec.
X1K	(200 Hz to 21 kHz)	2 sec.
X10K	(2.1 kHz to 210 kHz)	2 sec.

Table II-2. MAXIMUM LOCK-ON TIME FOR EACH BAND

*Time can be shortened appreciably by momentarily switching to INT/VCO mode and manually setting the oscillator to the proper frequency.

When the frequency has locked, the phase will track at the typical rates shown in Figure II-1.

EXTERNAL f/2: Essentially the same as the External mode, except the internal reference oscillator locks to twice the frequency of the external control signal. Maximum input frequency is 105 kHz.

PHASE SHIFTER: Phase accuracy is ±2° from 0.2 Hz to 21 kHz, and ±5° from 21 kHz to 210 kHz.

DEMODULATOR

The Function switch allows the Demodulator to operate as a Phase Sensitive Detector with selectable output gain or as a conventional ACVM.

DC OUTPUT GAIN/ZERO STABILITY: The Function switch permits selection of the optimum gain versus stability trade-off for the characteristics of the signal being measured. The following table lists both the zero stability and overload capabilities at each switch setting.

OUTPUT GAIN	OUTPUT STABILITY	OVERLOAD CAPABILITY*
X1	15 ppm/°C	3 x full-scale
X10	100 ppm/°C	30 x full-scale
X100	1000 ppm/°C	300 x full-scale

Table II-3. OUTPUT STABILITY AND OVERLOAD AS A FUNCTION OF OUTPUT GAIN

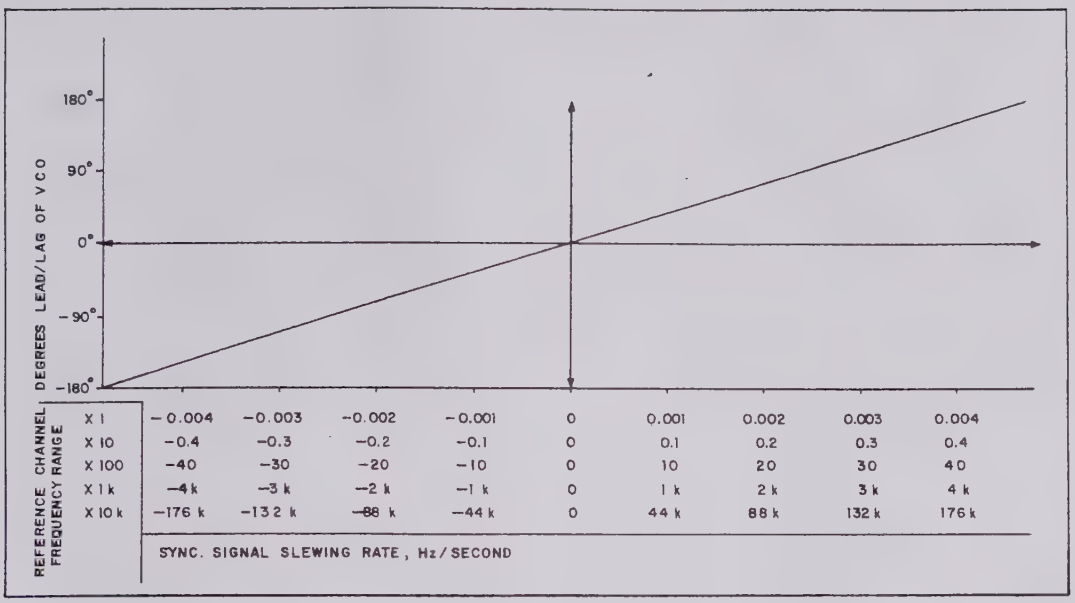
*Defined as the ratio, at the input of the lock-in amplifier, of the maximum pk-pk non-coherent signal which can be applied without overloading the Model 126 to the pk-pk coherent signal required to yield full-scale Model 126 output meter deflection. Note that, expressed as the ratio of the pk-pk non-coherent signal to the rms value of the coherent signal required for full-scale output, this number can be as great as 1000 (maximum input signal: 3 V pk-pk).

OUTPUT FILTER OPERATING MODES

6 dB: Single section low pass filter with Time Constant switch selections of 1 ms to 300 s in a 1-3-10 sequence plus minimum (MIN.) and external (EXT.). Rolloff rate is 6 dB/octave.

12 dB: Double section low pass filter with the same range of settings as for 6 dB/octave. Rolloff rate is 12 dB/octave.

INTEGRATE: A true integrate mode may be selected at the front panel. Build-up rate is such that a full scale signal will cause the output to reach the usual full scale level after a time interval equal to the time constant selected by the Time Constant switch has elapsed. The Integrate mode is often used to measure signals which are not continuously present at the input. Accuracy is ±20%.



REFERENCE CHANNEL FREQUENCY RANGE									
X 1	-0.004	-0.003	-0.002	-0.001	0	0.001	0.002	0.003	0.004
X 10	-0.4	-0.3	-0.2	-0.1	0	0.1	0.2	0.3	0.4
X 100	-40	-30	-20	-10	0	10	20	30	40
X 1 k	-4 k	-3 k	-2 k	-1 k	0	1 k	2 k	3 k	4 k
X 10 k	-176 k	-132 k	-88 k	-44 k	0	44 k	88 k	132 k	176 k

SYNC. SIGNAL SLEWING RATE, Hz/SECOND

Figure II-1. SYNC. SIGNAL SLEWING RATE
AS A FUNCTION OF RANGE

HOLD/NORMAL AND RESET: A set of two switches can be used for holding or resetting the output level in any of the three Output Filter operating modes. The Hold/Normal switch can be used to determine the integrating time limits. Output stability when holding is typically 200 ppm of full-scale per time constant interval.

EQUIVALENT NOISE BANDWIDTH: 416 μHz minimum (300 seconds maximum internal time constant, 12 dB/octave).

ZERO SUPPRESS: Calibrated control permits off-setting zero by ±1000% on the X10 and X100 ranges, and ±300% on the X1 range of the Function switch.

METERED OUTPUTS: Standard panel meter is 0.5% linear. Full-scale corresponds to ±10 V at the front panel Function Out connector (1 kilohm impedance) and at the recorder output binding posts (1 kilohm impedance).

ACVM ACCURACY: ±1% from 10 Hz to 20 kHz, increasing to ±10% at 210 kHz; +0, -30% below 10 Hz. Average responding.

TEMPERATURE RANGE: 15°C to 45°C.

POWER REQUIREMENTS: 105-130 V or 210-260 V; 50-60 Hz; 30 watts.

SIZE: 6-31/32" H x 17-1/8" W x 18-1/4" D (17.8 cm H x 43.6 cm W x 46.5 cm D).

MOUNTING: Brackets included for mounting in standard 19" rack.

WEIGHT: 30 lbs.

NOTE: Specifications subject to change without notice.

SECTION III
INITIAL CHECKS

3.1 INTRODUCTION (SEE SAFETY NOTICE THAT PRECEDES SECTION I BEFORE OPERATING INSTRUMENT)

The following procedure is provided to facilitate initial performance checking of the Model 126. In general, the procedure should be performed after inspecting the instrument for shipping damage (any noted to be reported to the carrier and to Princeton Applied Research Corporation), but before using it experimentally. Should any difficulty be encountered in carrying out these checks, contact the factory or one of its representatives, a list of whom appears at the end of the manual.

3.2 EQUIPMENT NEEDED

(1) General-purpose oscilloscope.

(2) Signal generator, having any 1 kHz repetitive waveshape that crosses its mean exactly twice each cycle and having a peak-to-peak voltage of at least 100 mV.

(3) Assorted BNC cables.

3.3 PROCEDURE

NOTE: This procedure must be performed in sequence.

(1) Install a preamplifier if not already installed.

(2) Check the rear panel 115/230 switch. Be sure the number showing in the window corresponds to the line voltage to be used.

(3) Turn the front panel Power switch OFF.

(4) Plug the line cord into the rear panel and wall receptacles.

(5) Set the front panel controls as follows.

Meter	Check mechanical zero. Adjust if necessary.
Preamplifier	Select A input and DIRECT (if applicable).
Sensitivity switch	50 mV (if using a Model 118 Preamplifier, set the Sensitivity switch to 500 mV).
L.F. Rolloff	MIN.
H.F. Rolloff	MAX.
Frequency Mode switch	INT/VCO
Reference Frequency dials	Red knob, NORMAL; Digits, 4.0
Reference Frequency Range	X100
Phase potentiometer	0° (fully ccw).
Phase switch	0°

Hold/Normal switch ---------- NORM.
Time Constant switch ---------- Red knob, 6 dB; Black knob, 300 ms.
Function switch ---------- ACVM
Zero Offset ---------- 0 (fully ccw).
10X Full Scale switch ---------- OFF (center position).
(Zero Offset toggle switch)

(6) Turn the Power switch ON and wait five minutes for warmup.*

(7) Connect a cable between the Reference OUTPUT connector and the preamplifier's A input.

(8) Adjust the Reference Level potentiometer for a full-scale reading to the right. The resulting position of the Level control should be between the 10 mV and 100 mV marks on the front panel.

(9) Change the L.F. Rolloff switch setting to 1 kHz. The meter should read between 30% and 50% of full-scale. Return the switch to MIN.

(10) Change the H.F. Rolloff switch to 100 Hz. The meter should read between 15% and 40% of full-scale. Return the switch to MAX.

(11) Change the Time Constant switch setting to 10 sec. The meter should read full-scale.

(12) Place the Hold/Normal switch to HOLD. The meter should still indicate full-scale.

(13) Change the red Time Constant switch to INTEGRATE.

(14) Press the Reset button momentarily. The meter should read zero.

(15) Place the toggle switch to NORM. for exactly five seconds, and then return to HOLD. The meter should read approximately half-scale.

(16) Set the Time Constant switches to 300 ms and 12 dB/OCTAVE. Set the toggle switch to NORM. The meter should read full-scale.

(17) Change the Function switch to X1. The meter should again read full-scale.

(18) Set the Function switch to X10 and readjust the Reference Level control to obtain full-scale.

(19) Set the Zero Offset toggle switch to +, and the turns counting dial fully clockwise. The meter should be against the left-hand limit and the Overload lamp should be on.

(20) Set the Function switch to X100. The meter should be somewhere on scale, either positive or negative, and the Overload lamp should be off.

(21) Return the Function switch to X10 and the Zero Offset switch to OFF

*In a real measurement application, allow a one hour warmup period for optimum performance.

(center position). The meter should read full-scale.

(22) Place the Phase switch to 90°. The meter should go to zero ±20%.

(23) Set the Phase switch to 180°. The meter should read negative full-scale (to the left).

(24) Set the Phase switch to 270°. The meter should read zero ±20%.

(25) Turn the Phase potentiometer nine full turns clockwise (90°). The meter should read full-scale to the right.

(26) Connect the signal generator's output to the Input connector in the Reference Channel section of the front panel. The peak-to-peak voltage can be anywhere between 100 mV and several volts. Set the frequency to approximately 1 kHz.

(27) Disconnect the cable between the Reference Channel output connector and the preamplifier.

(28) Advance the Level control to the 1 V setting.

(29) Monitor the Reference Channel Output connector with the oscilloscope. The waveform should be a sine wave, 2.8 V (±0.3 V) peak-to-peak. (If the Power Amplifier Option has been installed, the amplitude will be a factor of ten greater.)

(30) Place the Reference Mode switch to EXT. The Unlock lamp should glow momentarily. During this time the frequency of the oscilloscope waveform should have increased to where it is equal to the frequency of the signal generator.

(31) Note the frequency on the oscilloscope. Then place the Mode switch to EXT. f/2; the frequency should double.

This completes the Initial Checks. If the instrument performed as indicated, one can be reasonably sure that it is operating properly.

SECTION IV
OPERATING INSTRUCTIONS

4.1 INTRODUCTION (SEE SAFETY NOTICE THAT PRECEDES SECTION I BEFORE OPERATING INSTRUMENT)

The PARC Model 126 Lock-In Amplifier is a precision instrument crafted to permit detailed analysis of signals buried in noise or other interference. This section describes the block diagram operation, full consideration of the function of each control, and the interfacing of the Model 126 with both the experiment and ancillary equipment. For a cursory method of setting the controls, at the expense of overlooking the reasoning behind certain steps, see the Condensed Operating Instructions, Section I. For more specific information on the operation within one of the circuit blocks, refer to the Theory and Circuit Description section. Beginning with an overall assessment of the instrument and following with full disclosures of each operational trait, this section is confined to mastering the controls of the instrument and connecting it to an experiment in the best manner.

4.2 BLOCK DIAGRAM AND FRONT PANEL LAYOUT

When operating as a Lock-In Amplifier, the Model 126 comprises three distinct sections, the Signal Channel, Reference Channel, and Phase Sensitive Detector along with its output circuitry; each is clearly separated at the front panel by heavy black lines. A typical situation is shown in Figure IV-1. To improve clarity the interference which might be present at the output of the experiment is not shown. The signal being measured, combined with any interference, is amplified by the Signal Channel which has a variable bandwidth capable of rejecting a large amount of the interference before submitting the signal to the Detector. The Reference Channel has the twofold function of driving the experiment so that the frequency of its signal output is known, and switching the Detector at exactly the same frequency but with an adjustable phase. Therefore, the Detector receives both a signal with its interference and a frequency reference of known phase. From these two inputs, the Detector produces sum and difference frequencies. The difference between the signal and the reference is, of course, zero frequency or simply dc, with an amplitude proportional component of the signal at the set phase. All interference and noise not at the reference frequency appear at the Detector's output at frequencies greater than zero. By sending the total Detector output through a lowpass filter, only the dc is present to deflect the meter a calibrated amount.

4.3 SIGNAL CHANNEL

PREAMPLIFIERS

The first decision to be made when placing the Model 126 in operation is the choice of plug-in preamplifier. The choice is based on consideration of the noise figure, common mode rejection ratio, and distortion, for the particular signal source characteristics. Generally, for very low signal levels, the selected preamplifier model yields the lowest noise figure for the source resistance and frequency of the signal being measured. Four models are presently available for voltage amplification and one model for current-to-volt-

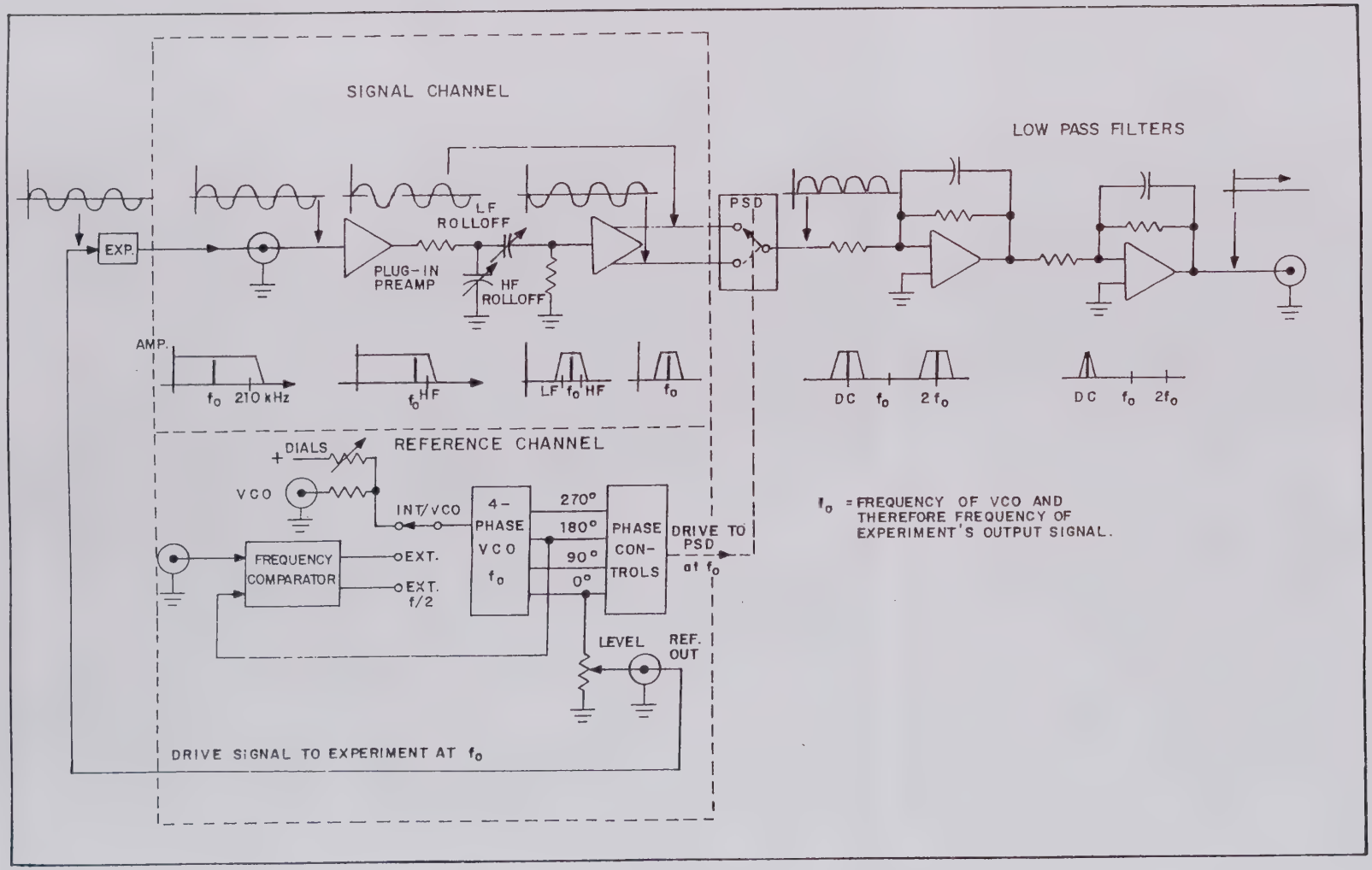


Figure IV-1. SIMPLIFIED BLOCK DIAGRAM

age conversion (often used with photomultiplier tubes).

Figure IV-2 shows the area in which the noise contributed by the preamplifier is insignificant compared to that which must be present in the source resistance due to thermal agitation. The Model 117 is well suited for signals from relatively high source resistances. The Models 116 and 119 are identical in operation from high source resistances but have an input impedance matching transformer which can be switched in to allow low noise performance

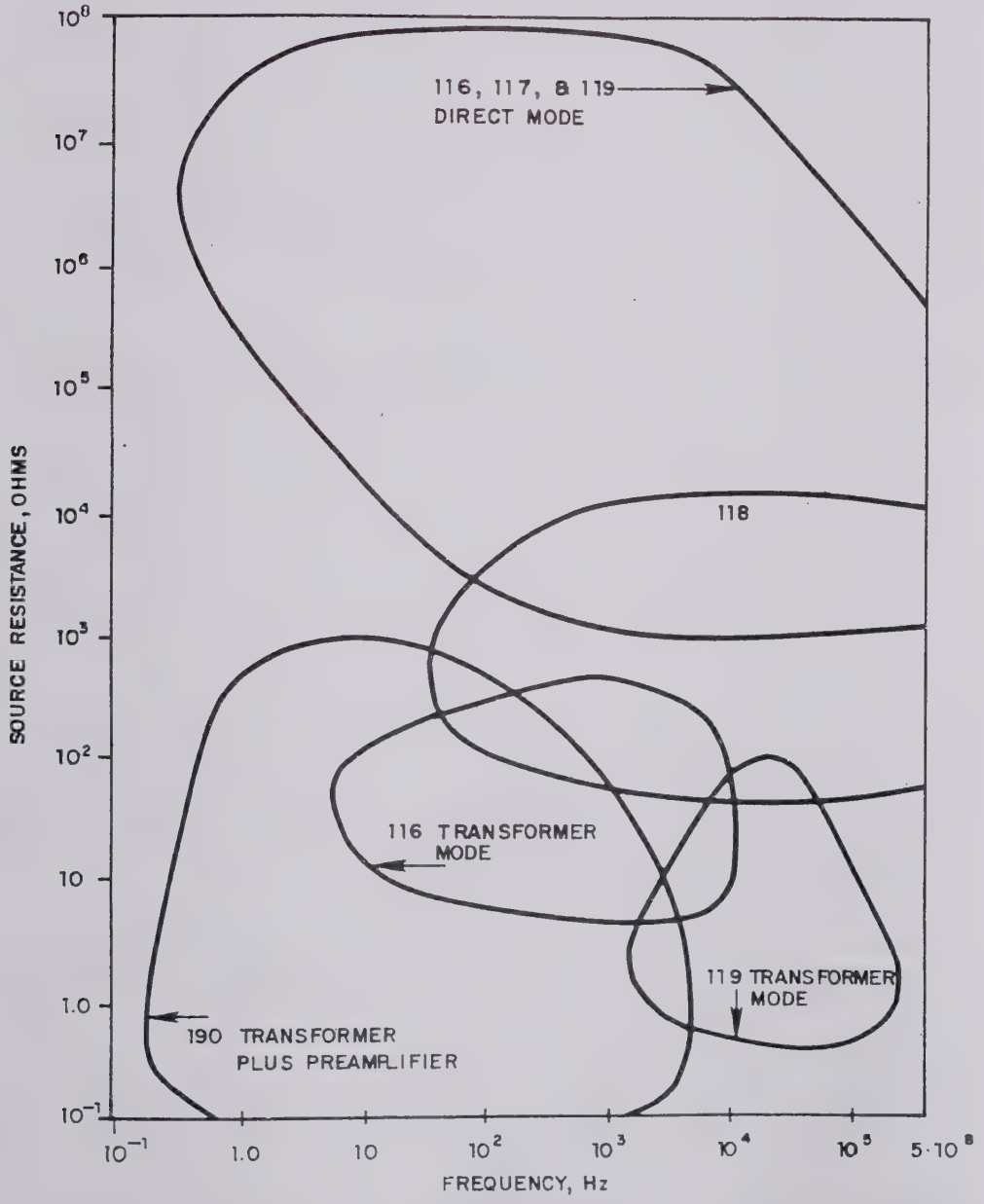


Figure IV-2. OPTIMUM PERFORMANCE REGIONS OF THE PREAMPLIFIERS

from very low source resistance values. The difference between the two is the optimum frequency range for the transformer type used in each model. The Model 118 performs well with intermediate values of source resistance.

Although not actually a preamplifier, the Model 190 Low Noise Transformer should be considered at this time. This transformer, when placed ahead of a high input impedance preamplifier such as the Model 116, 117, or 119, forms a system which has an optimum noise figure contour as shown in Figure IV-2. Both 1:100 and 1:1000 turns-ratios are provided.

A detailed discussion of noise figures is given in later paragraphs under "Use of Noise Figure Contours".

The Model 184 Photometric Preamplifier provides an input calibrated in terms of current ranging from 10^{-5} amperes per volt to 10^{-9} amperes per volt, permitting easy, accurate measurements of photodetector current, or any other minute current. Overall system sensitivity is the ampere/volt setting of the Model 184 multiplied by the Sensitivity and Output Gain settings of the Model 126, permitting measurement of currents as small as 10^{-15} ampere full scale. For typical noise figure information for the Model 184, refer to the instruction manual for that preamplifier.

Another factor in selecting a preamplifier is its ability to amplify without distortion. If an experiment requires measurement of low level harmonics in the presence of a high level fundamental, it is important that the preamplifier does not add significant harmonic signals by non-linear amplification of the fundamental. With the single exception of the Model 118, P.A.R. preamplifiers operating in the Direct mode distort a signal so slightly as to be unmeasurable (much less than 0.01%) using conventional methods. The Model 118 can, at high signal input levels, cause appreciable distortion as shown in Figure IV-3. When using the Models 116 or 119 in the transformer mode, both phase shift and distortion can occur and should be measured for each individual operating condition.

Common mode rejection ratio is an important consideration when the signal being measured has a high level of interference common to both terminals across which the signal appears. This type of interference is rejected by the preamplifier itself so that the signal to noise ratio "improvement" is in addition to the improvement made by the lock-in process. Figure IV-4 depicts the typical common mode rejection curves of the preamplifiers in both the direct and transformer modes operating differentially (A - B).

The full scale sensitivity of the Model 126 Lock-In Amplifier can be affected by the choice of preamplifier. Refer to the paragraphs on Full Scale Sensitivity on page IV-14.

USE OF NOISE FIGURE CONTOURS

If every precaution is taken to insure that the signal being measured is not contaminated by such things as line frequency interference and ground loops, there is still a residual noise, the Johnson noise, which is present due to the thermal effects on the electrons in the source resistance at any temperature above absolute zero. This thermal noise can be calculated from the following equation:

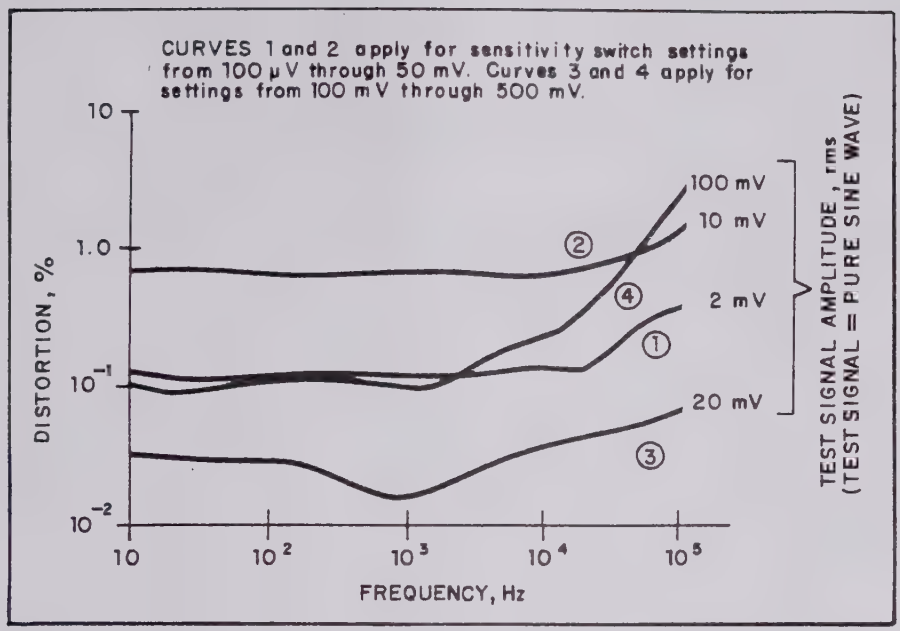


Figure IV-3. DISTORTION v. FREQUENCY AND AMPLITUDE, MODEL 118 ONLY

$$E_n = \sqrt{4KTR_S B_N} \qquad (1)$$

where:

E_n = rms noise voltage within a bandwidth of measurement.
K = Boltzmann's constant = 1.38×10^{-23} joules/Kelvin.
T = Absolute temperature in Kelvins.
R_S = Resistive component of the impedance across which the voltage is measured.
B_N = Bandwidth across which the noise voltage is measured.

Since room temperature is the most common situation for signal sources, the graph shown in Figure IV-5 which relates the Johnson noise per root-Hertz for a range of source resistances at room temperature has been provided.

A second source of noise must also be considered. Every amplifier of any type or design also has a certain level of internally generated noise which appears at its output. It can be seen that whenever any signal is passed through an amplifier there will be a certain amount of noise added to that already inherent in the signal source. One way of evaluating the practical importance of these two types of noise is to relate them by determining the "Noise Figure" for a preamplifier according to the following formula:

Noise Figure =

$$20 \log_{10} \frac{\text{total rms noise voltage referred to the amplifier input}}{\text{source thermal rms noise voltage}} \text{ dB} \qquad (2)$$

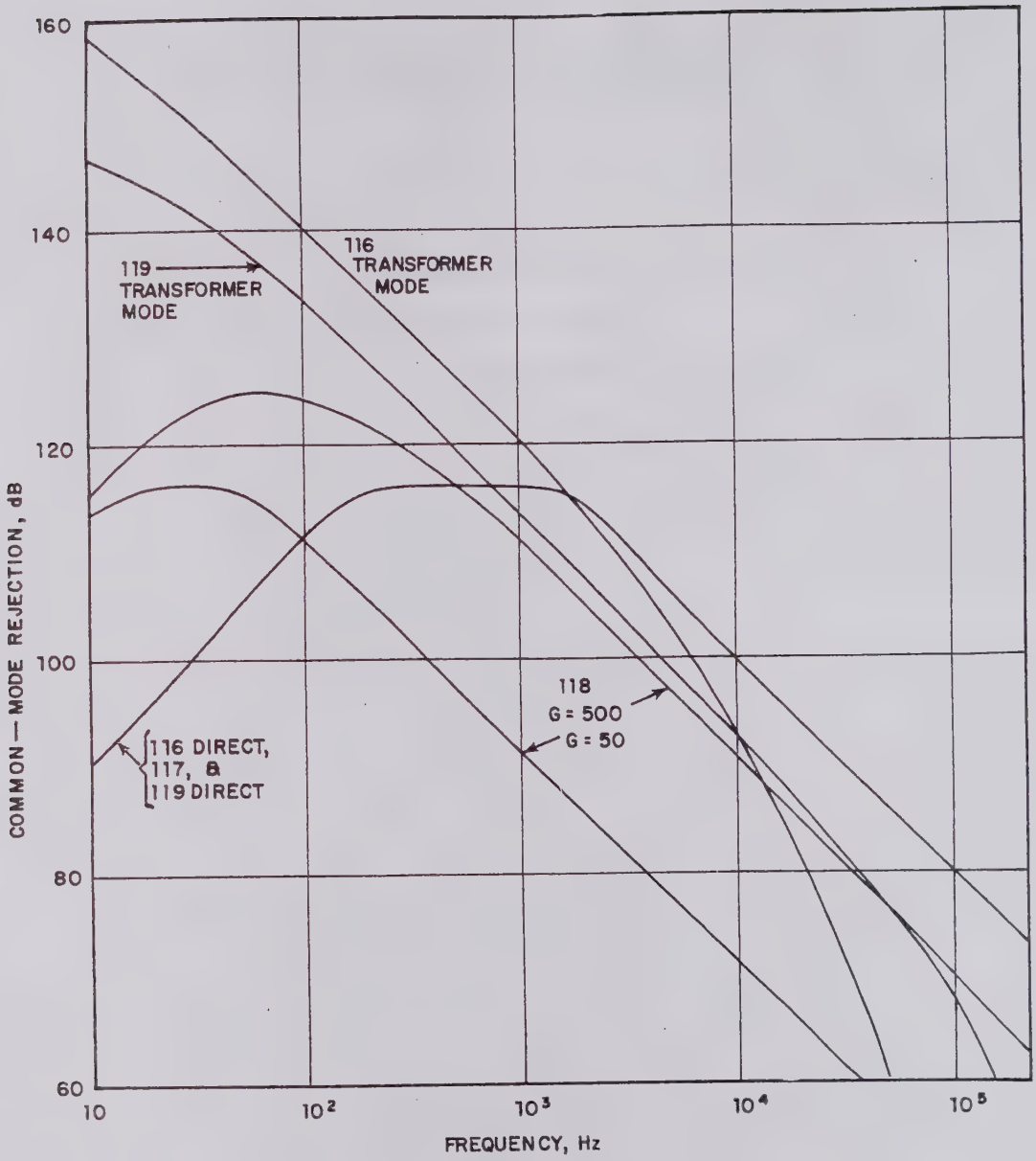


Figure IV-4. TYPICAL COMMON-MODE REJECTION

Since the noise contributed by a given preamplifier depends on the particular resistance connected to its input and also on the frequency of interest, the noise figure for that preamplifier can be plotted as a set of contours against frequency and resistance axes. Contours for the various plug-in preamplifiers are given in Figures IV-6 through IV-9. Additional information pertaining to the Model 190 is included in Figures IV-10 through IV-12. The inner areas with the lower noise figure values are located where the preamplifiers contribute a negligible amount of noise compared to the noise due to the source resistance. If the characteristics of the signal source are

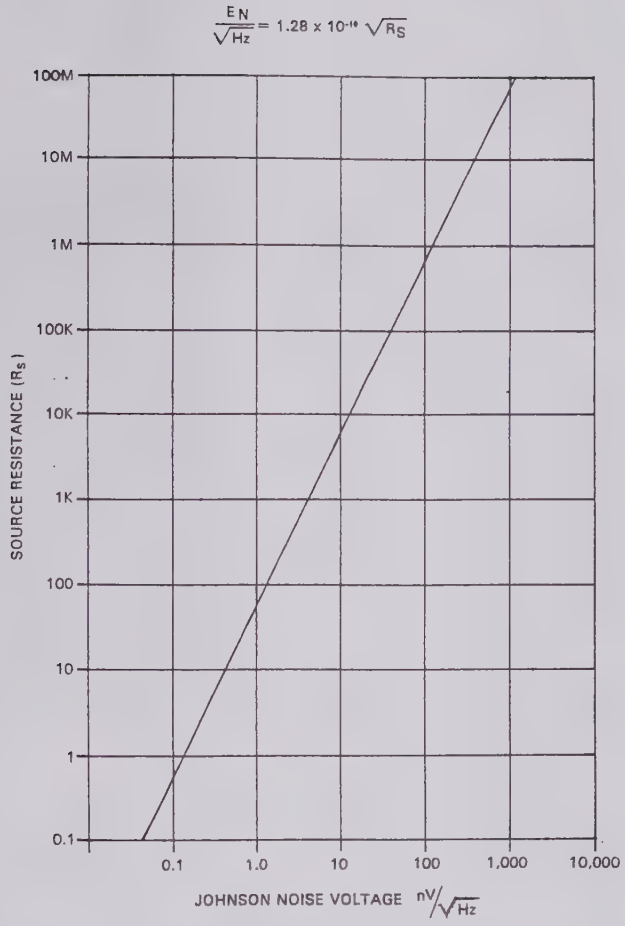


Figure IV-5. JOHNSON NOISE VOLTAGE FROM A RESISTANCE AT ROOM TEMPERATURE (290 K)

known, it is a simple matter to determine which preamplifier is most appropriate and whether it should be operated with direct or transformer coupled inputs.

It is important to note that if the source resistance of the signal is lower than that which would be optimum for a given preamplifier, the source resistance should not be changed by merely adding a series resistor to it. To do so would actually result in a degraded signal-to-noise ratio although the noise figure has improved (only because more thermal noise has been introduced at the input without a change in signal level). A similar result occurs if a shunt resistor is added to a source which is higher than the optimum value for a preamp; in this case, the effect is to reduce the signal level more rapidly than the thermal noise. A transformer can often be used to advantage since, over certain ranges, the apparent source resistance as seen by the preamplifier can be changed to optimum without degrading the signal to noise ratio.

Suppose that the Model 126 is to be connected to an experiment that presents

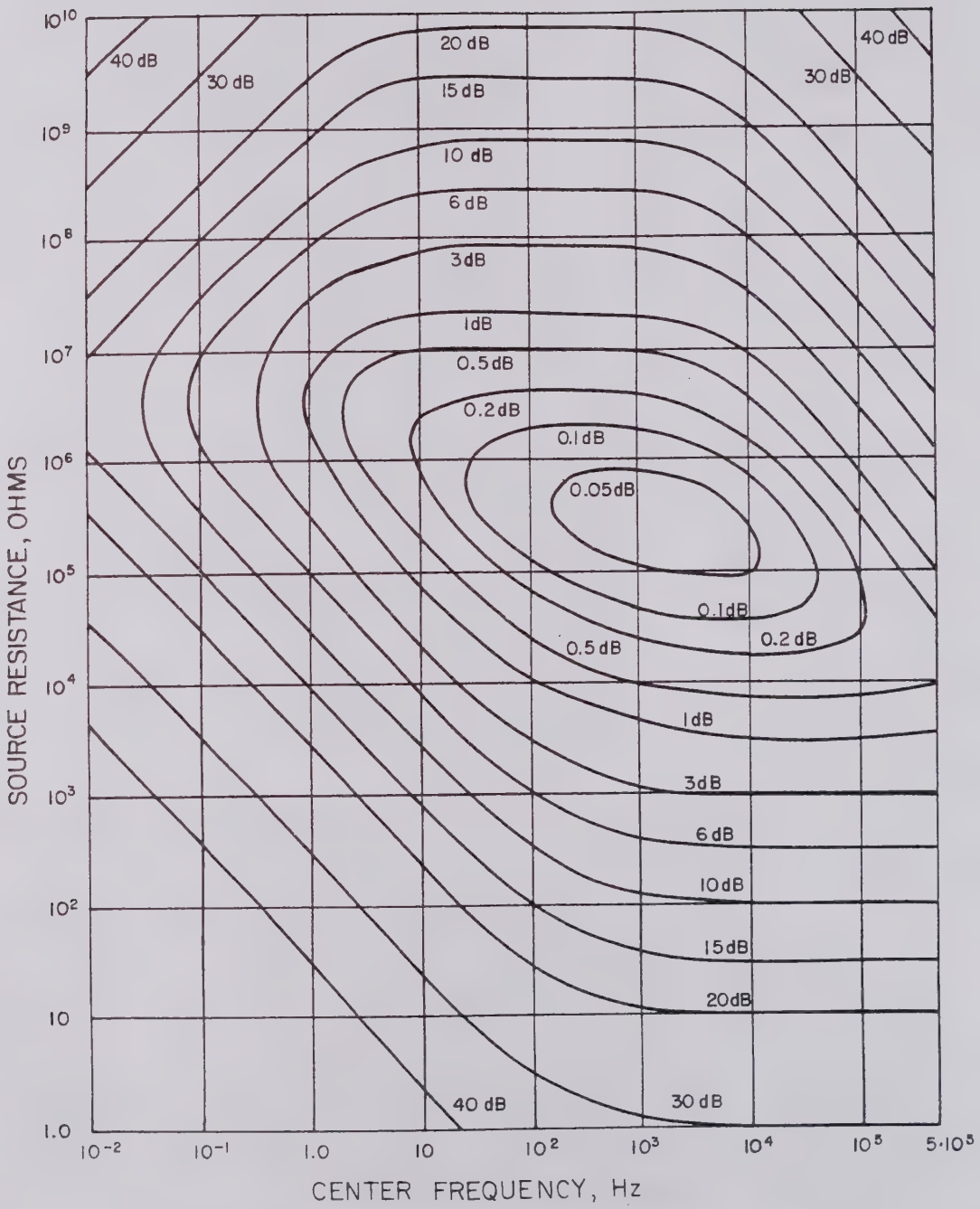


Figure IV-6. TYPICAL NOISE FIGURE CONTOURS FOR MODEL 117 AND 116 & 119 OPERATING IN THE DIRECT MODE

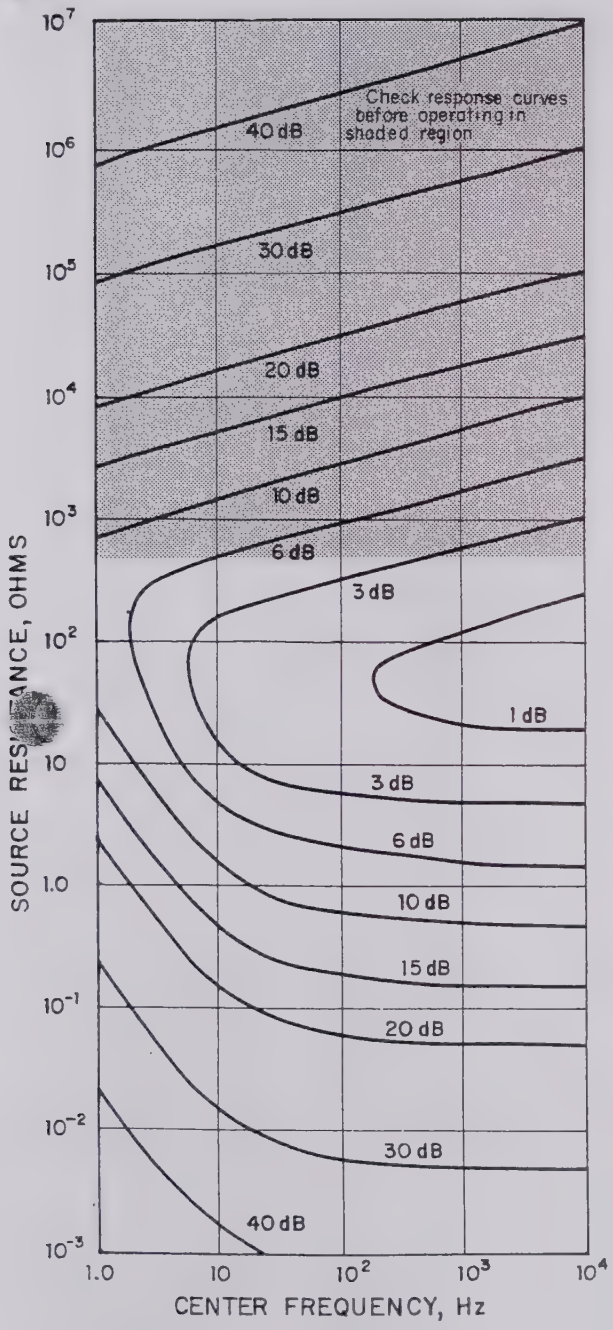


Figure IV-7A. TYPICAL NOISE FIGURE CONTOURS FOR MODEL 116 OPERATING IN THE TRANSFORMER MODE

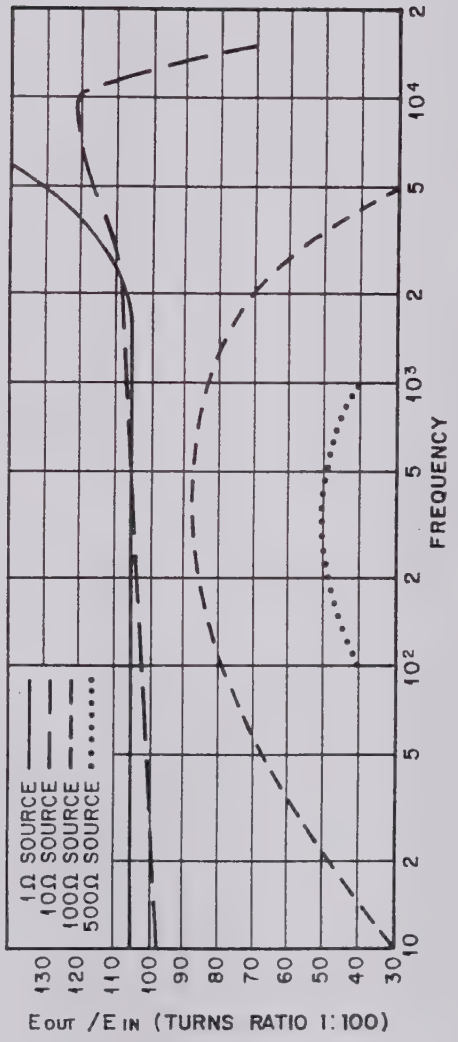


Figure IV-7B. TYPICAL AMPLITUDE TRANSFER CURVES FOR MODEL 116 OPERATING IN THE TRANSFORMER MODE

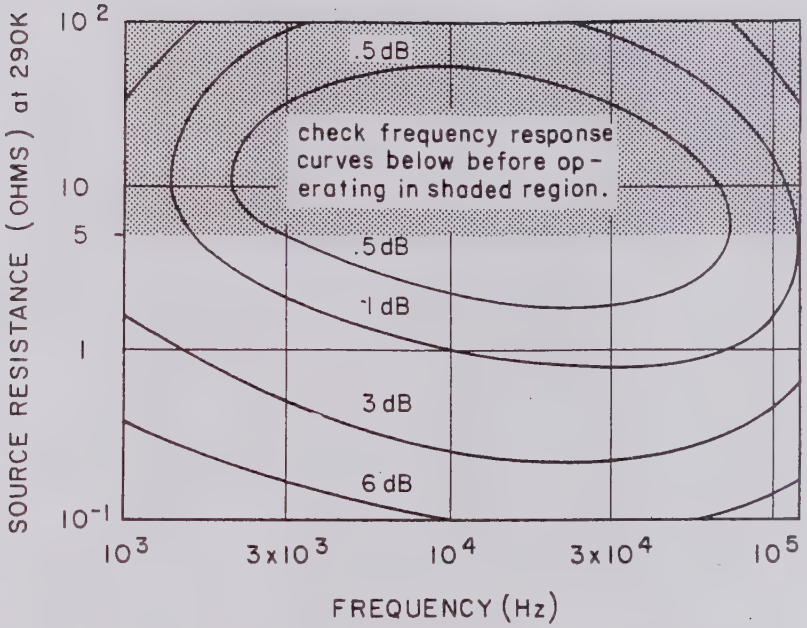


Figure IV-8A. TYPICAL NOISE FIGURE CONTOURS FOR MODEL 119 OPERATING IN THE TRANSFORMER MODE

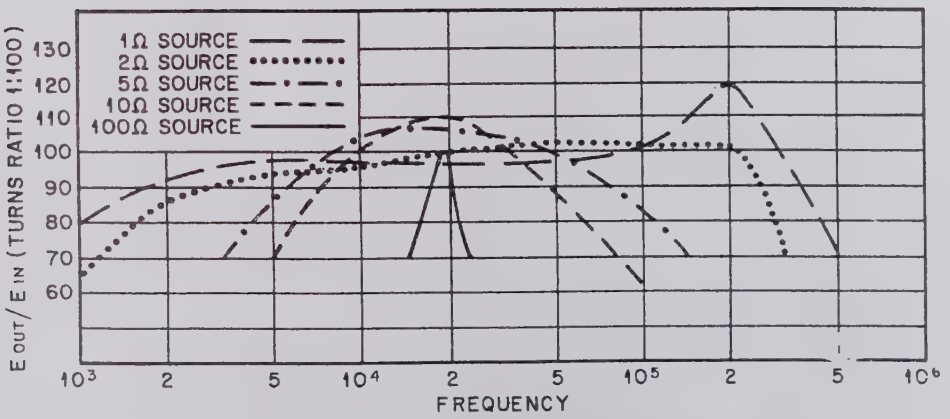


Figure IV-8B. TYPICAL AMPLITUDE TRANSFER CURVES FOR MODEL 119 OPERATING IN THE TRANSFORMER MODE

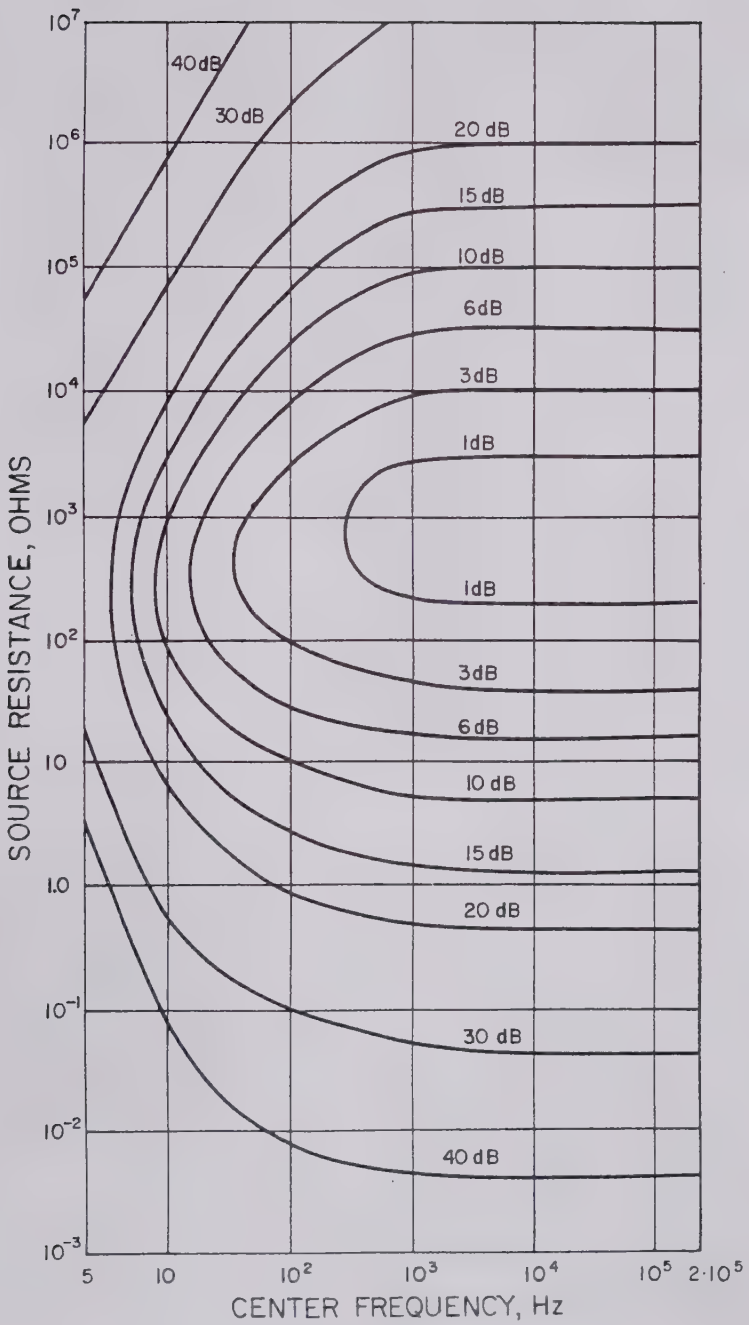


Figure IV-9. TYPICAL NOISE FIGURE CONTOURS FOR MODEL 118

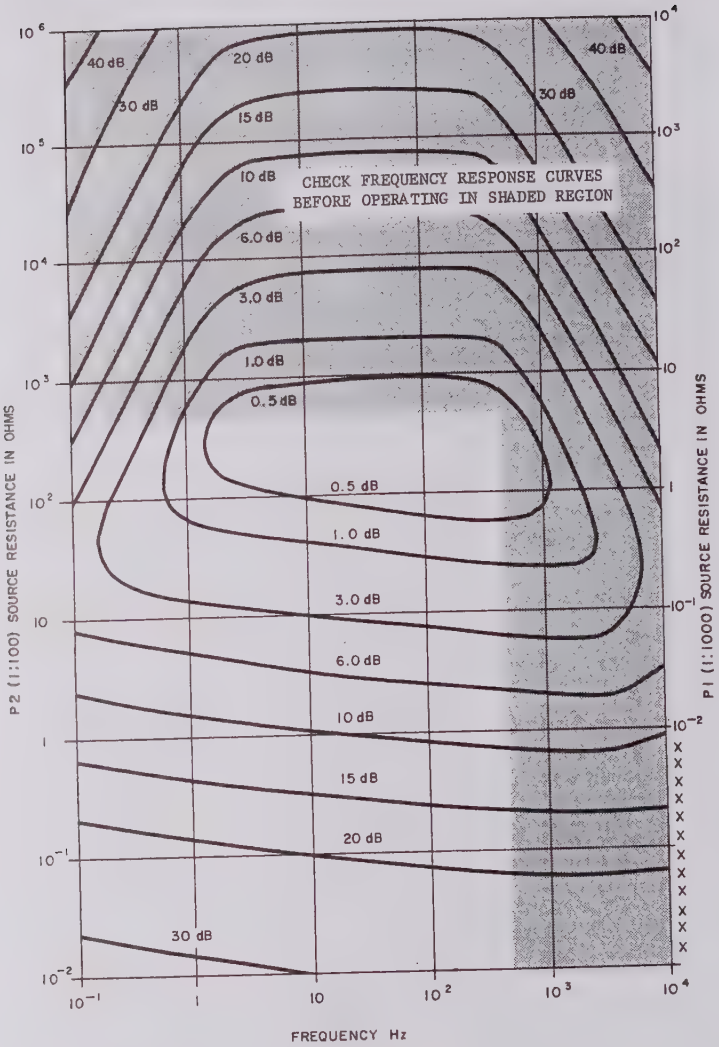


Figure IV-10A. TYPICAL NOISE FIGURE CONTOURS FOR MODEL 190-113 SYSTEM

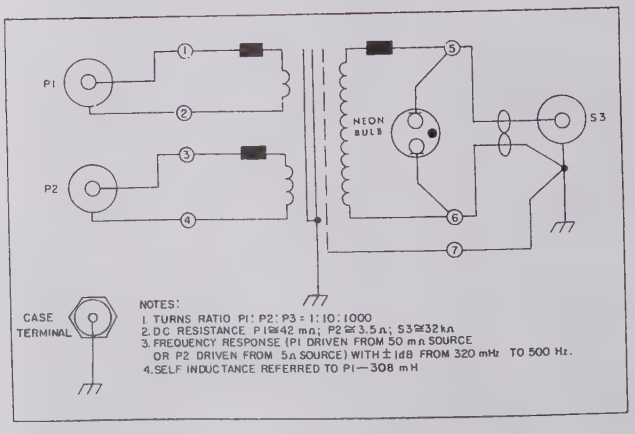

P1
P2
NEON BULB
S3
CASE TERMINAL
NOTES:
1. TURNS RATIO P1: P2: P3 = 1:10:1000
2. DC RESISTANCE P1≅42 mΩ; P2≅3.5Ω; S3≅32kΩ
3. FREQUENCY RESPONSE (P1 DRIVEN FROM 50 mΩ SOURCE OR P2 DRIVEN FROM 5Ω SOURCE) WITH ±1dB FROM 320 mHz TO 500 Hz.
4. SELF INDUCTANCE REFERRED TO P1—308 mH

Figure IV-10B. 190 WIRING DIAGRAM

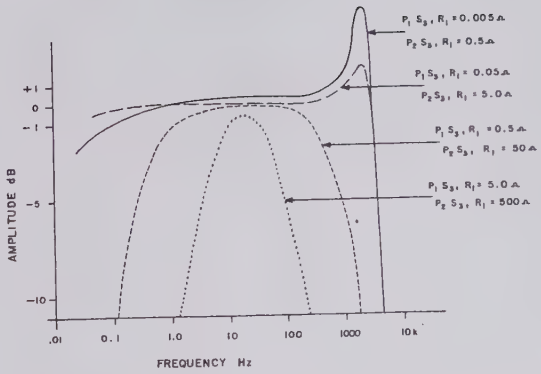


Figure IV-10C. TYPICAL AMPLITUDE TRANSFER CURVES FOR MODEL 190

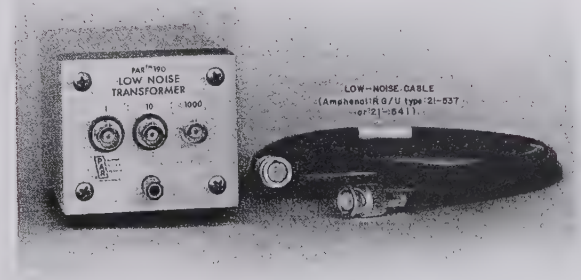


Figure IV-10D. PHOTO OF MODEL 190 TRANSFORMER

A magnetized transformer is usually noisy and microphonic compared to when it is not magnetized. This noise is the most objectionable characteristic of a magnetized transformer because it affects low level signals. The distortion of high level signals described here is not usually an operating problem because the signal is seldom so large. But high level distortion is useful in determining the condition of the core and in monitoring the degaussing pro-

Notice from Figure III-11A that as long as the core is not magnetized the transformer works on a loop around center line #1 and the signal can be of maximum amplitude. If the core becomes permanently magnetized, the transformer works on a loop around center-line #2 (or equivalent for opposite polarity), and, if the same maximum signal current is applied, the core becomes saturated at one of the peaks of the signal. B, C, and D of Figure III-11 show a primary signal current, corresponding core magnetization, and corresponding induced secondary voltage for a magnetized-core transformer with large signal input. Notice that the permanently magnetized core saturates sooner for one polarity of signal and later for the other polarity.

To demagnetize (degauss) the transformer, it is necessary to pass a relatively large ac current through the primary, then to very slowly decrease this current. The secondary should be open (for the Model 116, disconnect pins 4 and 5 on the circuit board). The degaussing current is initially large enough to magnetize the core in the direction of each corresponding polarity excursion of this current, and overrides the initial magnetization. The object of decreasing the current slowly is so that each successive magnetization is slightly less than the preceding one of the opposite polarity. As the current is decreased, the core is progressively less magnetized until it is no longer magnetized at all. Figures III-12A, B, and C illustrate the secondary waveforms as the transformer becomes demagnetized. IMPORTANT: Use a LOW FREQUENCY degaussing current, 1 Hz or so, to avoid inducing excessively high voltage in the secondary, and monitor the secondary with a high impedance oscilloscope. The Model 190's secondary is protected with a neon lamp, but the Model 116's transformer could suffer insulation breakdown if the operator is not careful.

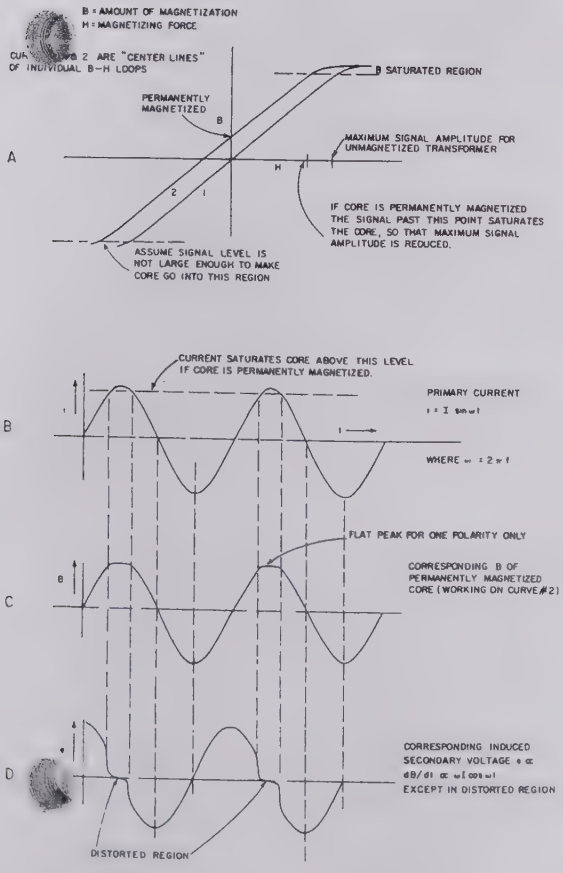

B = AMOUNT OF MAGNETIZATION
H = MAGNETIZING FORCE
CURVES 1 AND 2 ARE "CENTER LINES" OF INDIVIDUAL B-H LOOPS
B SATURATED REGION
PERMANENTLY MAGNETIZED
B
A
H
MAXIMUM SIGNAL AMPLITUDE FOR UNMAGNETIZED TRANSFORMER
2
1
IF CORE IS PERMANENTLY MAGNETIZED THE SIGNAL PAST THIS POINT SATURATES THE CORE, SO THAT MAXIMUM SIGNAL AMPLITUDE IS REDUCED.
ASSUME SIGNAL LEVEL IS NOT LARGE ENOUGH TO MAKE CORE GO INTO THIS REGION
CURRENT SATURATES CORE ABOVE THIS LEVEL IF CORE IS PERMANENTLY MAGNETIZED.
PRIMARY CURRENT
i = I sin ωt
B
i
WHERE ω = 2πf
FLAT PEAK FOR ONE POLARITY ONLY
CORRESPONDING B OF PERMANENTLY MAGNETIZED CORE (WORKING ON CURVE #2)
B
C
CORRESPONDING INDUCED SECONDARY VOLTAGE e ∝ dB/dt ∝ ωI cos ωt
EXCEPT IN DISTORTED REGION
e
D
DISTORTED REGION

Figure IV-11. B-H CURVES AND WAVEFORMS

In determining the overall response of the Signal Channel, the transformer frequency response and the response of the Selective Amplifier in the Signal Channel must be combined. However, the noise figure contours given can be regarded as overall signal-channel contours.

Note the resonance peak at the high frequency end of the transformer response curves. If the signal has frequency components in this range the amplifier may be prematurely overloaded by them, particularly at high signal or gain levels. If high frequency signal components cause such problems the operator may consider prefiltering the signal, filtering in the Signal Channel, or changing the source impedance to flatten the response curve in this range.

If using an input transformer, either internal or external, phase shift and distortion may occur. The amount of phase shift and distortion must be measured for each individual set of operating parameters. Use a test sinewave of a purity that is consistent with the degree of accuracy required. The outer frequency may be notched out in the Signal Channel, so that only the distorted portion remains. The rms level of distortion may then be determined by operating the Detector in the ac voltmeter mode. In measuring the phase shift, it is worthwhile to set the filter controls in the positions to be used when measuring the experimental signal, so that the overall phase shift of the signal channel is accurately determined.

CAUTION: Avoid passing excessive dc current through the primary of these transformers. A magnetized transformer is usually noisy and microphonic, causing problems at low levels. At high levels, a magnetized transformer will saturate prematurely for one polarity of signal, thereby reducing the maximum peak signal amplitude that the transformer can handle without distortion. The transformer used in the Model 116 and the Model 190 transformer will permanently magnetize, so that once magnetized they will remain noisy until degaussed. More than 200 μA will magnetize the cores of these transformers. Do not measure winding resistance with an ohmmeter; ohmmeter current is sufficient to magnetize the core. The transformer used in the Model 119 has a ferrite core that will virtually not permanently magnetize, so that degaussing is not required.

DEGAUSSING PROCEDURE

All transformer cores saturate in magnetization (= B) after a given winding current has been reached (∝ H = no. turns x i = magnetizing force, where i = current through winding). The voltage induced in the secondary is proportional to dB/dt, so that the secondary voltage is distorted on that part of the curve where B is not a linear function of H. A permanently magnetized core saturates at a lower level of H, and thereby reduces the maximum signal current that can be transformed without distortion. Figure III-11A shows a B-H curve and waveforms that graphically illustrate this core saturation and corresponding distortion. Note that the B-H characteristic is actually a loop; curves #1 and #2 of Figure III-11A are only representative "center lines" of the corresponding loops. Actually, the loops are usually "squarish ovals," with different degrees of squareness for different core materials. The shape of the loop has much to do with distortion, but this is not of interest in this discussion, only the general situation of the loops with respect to saturation.

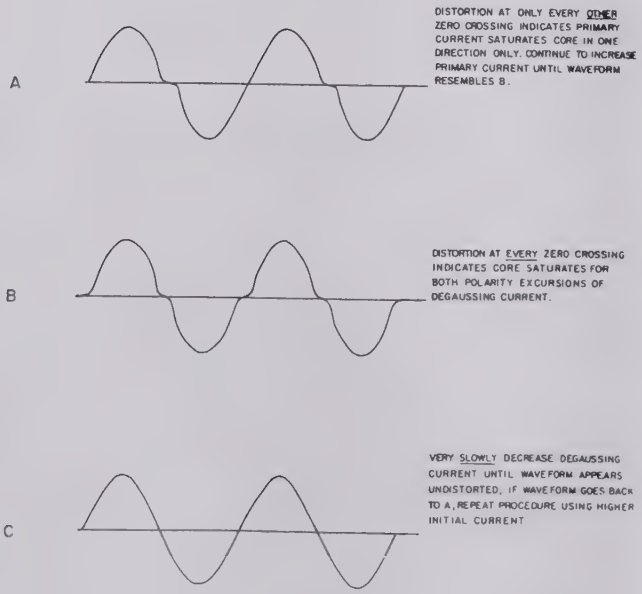

A
DISTORTION AT ONLY EVERY OTHER ZERO CROSSING INDICATES PRIMARY CURRENT SATURATES CORE IN ONE DIRECTION ONLY. CONTINUE TO INCREASE PRIMARY CURRENT UNTIL WAVEFORM RESEMBLES B.
B
DISTORTION AT EVERY ZERO CROSSING INDICATES CORE SATURATES FOR BOTH POLARITY EXCURSIONS OF DEGAUSSING CURRENT.
C
VERY SLOWLY DECREASE DEGAUSSING CURRENT UNTIL WAVEFORM APPEARS UNDISTORTED, IF WAVEFORM GOES BACK TO A, REPEAT PROCEDURE USING HIGHER INITIAL CURRENT

Figure IV-12. DEGAUSSING WAVEFORMS

a source resistance of 100 ohms and a signal frequency of 1 kHz. In Figure IV-6, it can be seen that the noise figure would be approximately 10 dB when using either a Model 117 or a 116 or 119 in the Direct mode. If the Model 116 were operated with the transformer switched in, a noise figure of less than 1 dB (Figure IV-7A) would be realized. In addition, the Model 118 (Figure IV-9) would be slightly higher than 1 dB under these signal conditions. Strictly from a noise figure standpoint, the Model 116 operated in the Transformer mode would be the best choice. Nevertheless, the frequency response curves for this transformer, Figure IV-7B, should be checked. It can be seen that the calibration will be affected, and this should be taken into account.

It should be emphasized that noise figure is not the only criterion in choosing a preamplifier, especially if the signal level is not small compared to the noise. A flat frequency response curve such as the Model 118 may be important if the operating frequency of the Model 126 must be scanned over a large range.

So far, actual noise voltages have not been discussed. This is because the voltage as given in Equation (1) depends on the bandwidth, which, under normal use of the Model 126 as a Lock-In Amplifier, is controlled by the setting of the Time Constant switch. The Noise voltage and the bandwidth is described in some detail in the "Output Filter Modes" paragraph in subsection 4.5.

FULL SCALE SENSITIVITY

Effect of Preamplifier Choice: The Sensitivity switch on the Model 126 has settings ranging from 100 μV to 500 mV full scale. The actual full-scale sensitivity is equal to the setting when using the Model 117 or either the Model 116 or 119 operated in the Direct mode. Use of the Transformer mode on the latter two will increase sensitivity by a factor of 100 so that the Sensitivity switch covers a range of 1 μV to 5 mV. The Model 118 boosts sensitivity by a factor of 10 so that a range of 10 μV to 50 mV results.

All of the foregoing assumes that the Output Gain (see PSD and Output Amplifiers) is set to X1. Increasing the Output Gain setting also affects the actual full scale sensitivity. Using the maximum setting of X100 in conjunction with the Model 116 or 119 Preamplifier in the Transformer mode yields a full scale sensitivity of 10 nV.

Optimum Settings: In general, regardless of what preamplifier or Output Gain is used, set the Sensitivity to the lowest full-scale voltage which does not cause overload as indicated by the lamp.

ROLLOFFS

The prime function of the low and high frequency rolloff circuits is to eliminate as much interference and noise as possible while having minimal effect on the signal of interest. Under most conditions, this increases the dynamic range of the instrument and reduces the fluctuations in the final dc output of the Model 126. As shown in the Block Diagram, Figure IV-1, the bandwidth of the signal channel can be set by individual High and Low Frequency Rolloff switches.

Use of the MIN. and MAX. positions simultaneously provides a flat response

curve over the full operating range of the Model 126 (refer to the specifications, subsection 2.2, Bandwidth). A flat response is useful for operation of the instrument as an ordinary ac voltmeter or as a broadband, low noise signal amplifier. When operating as a Lock-In, the flat response is recommended when the signal changes frequency by large factors during the course of the measurement.

Whenever possible, the bandwidth should be minimized so that the control settings closely bracket the signal frequency. While this can greatly reduce noise and interference which are not close to the signal frequency, bear in mind that there is also some effect on the amplitude and phase of the signal itself which could affect the apparent calibration of the phase controls and full-scale sensitivity. Figures IV-13 and IV-14 show the characteristics of each filter where E_{in} and E_{out} refer to the input and output voltage of each filter. E_{in} may or may not be the same for the two filters. To find the combined effect of the filters, multiply the Amplitude transfer fractions and add the Phase transfers.

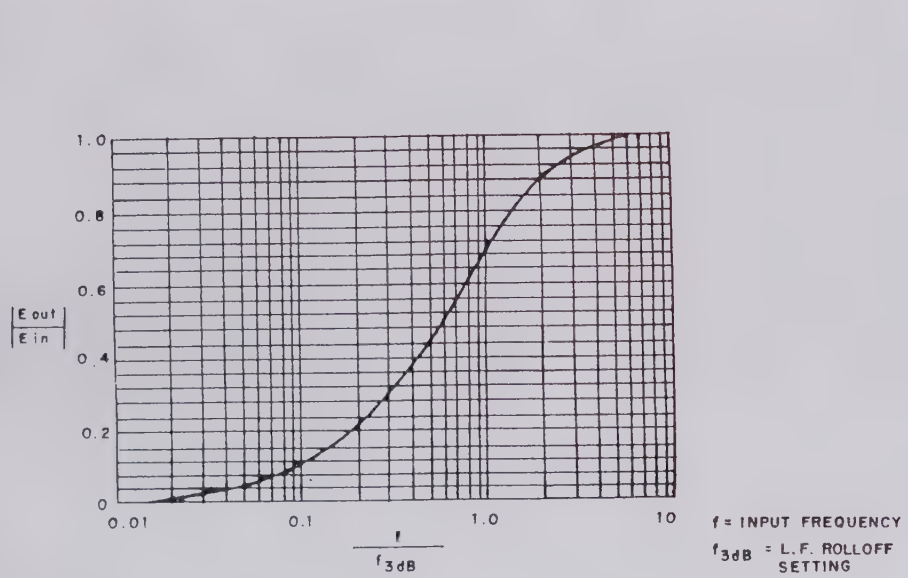
Suppose the signal frequency is 1 kHz and that both line frequency interference (50 or 60 Hz) and wideband noise are present and large compared to the signal. By setting the LF Rolloff to 100 Hz and the HF Rolloff to 10 kHz, it can be seen that the line frequency pickup is reduced to less than 0.5 times the level at the input of the filter, using an f/f_{3dB} value of 60 Hz/100 Hz in Figure IV-13. The bandwidth of the wideband noise has been reduced from the full bandwidth of the Model 126 to approximately 10 kHz. Wideband noise fed into the input of the amplifier produces a noise voltage at the output not only proportional to gain, of course, but also proportional to the square root of the bandwidth. In this case, the noise voltage at the output of the Signal Channel has been reduced by a factor of $\sqrt{210 \text{ kHz}/10 \text{ kHz}}$ or about 4.4.

Now what about the amplitude and phase shifts of the signal itself? For the LF Rolloff Phase Transfer, f/f_{3dB} is 1 kHz/100 Hz or simply 10. As shown in Figure IV-13, there is about a 7° lead imposed on the signal and negligible amplitude loss by the LF Rolloff under these conditions. The f/f_{3dB} value for the HF Rolloff is 0.1 which produces a similar effect except that the signal lags 7°. Although not necessary, separating both the LF and HF Rolloffs by the same factor with respect to the signal frequency cancels out the total phase shift through the filters.

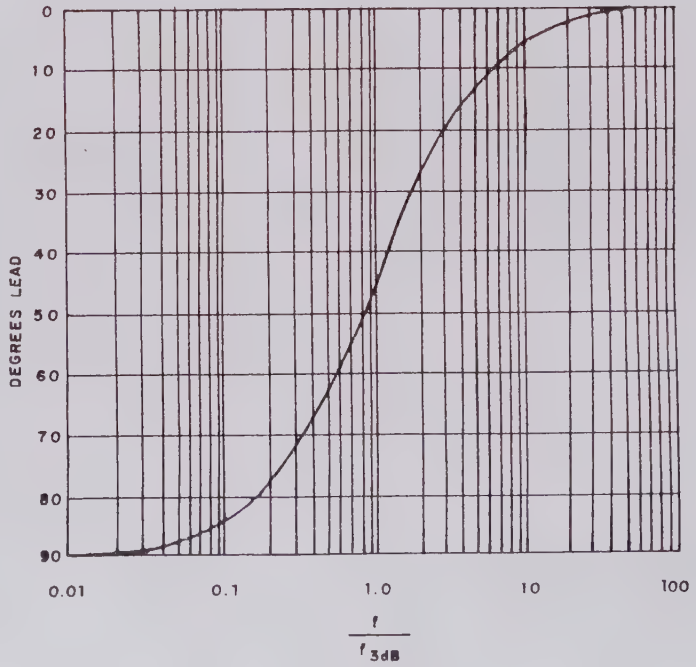
In some cases, maximum signal-to-noise ratio improvement can be obtained by operating the two filters at the same frequency and causing the signal to appear at that frequency. Again, the total phase shift is nominally zero, but in this situation, the signal amplitude is reduced by 6 dB or 0.5. Nevertheless, in the example of the preceding paragraph, the line interference is reduced to about 0.07 times the level at the input of the filter so that compared to the signal it is now much smaller. The amplitude reduction of the signal itself should be taken into account when considering full scale sensitivity.

OVERLOAD

The Overload lamp monitors two points in the Signal Channel, at the preamplifier output just ahead of the signal rolloffs, and at the final output just

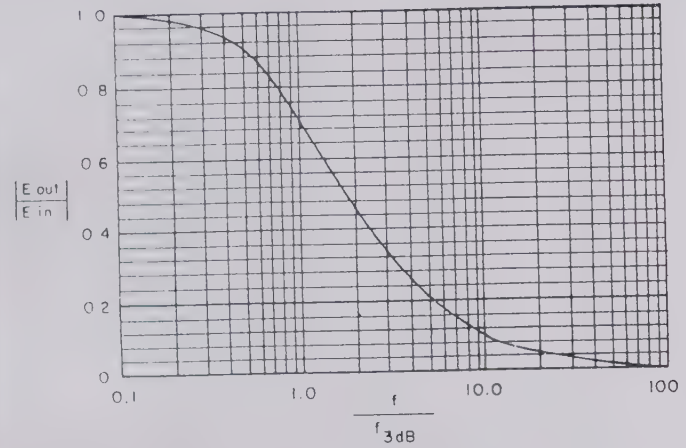


Amplitude Transfer



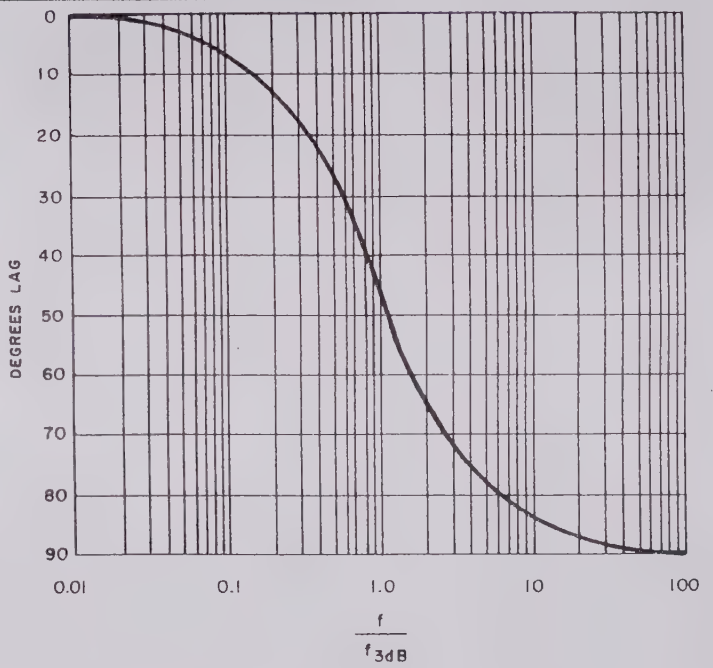
Phase Transfer

Figure IV-13. LOW FREQUENCY ROLLOFF CHARACTERISTICS



Amplitude Transfer

f = INPUT FREQUENCY
f_{3dB} = H.F. ROLLOFF SETTING



Phase Transfer

Figure IV-14. HIGH FREQUENCY ROLLOFF CHARACTERISTICS

ahead of the Phase Sensitive Detector. Not only is the possibility of saturating the last signal amplifier monitored, but overloads in the early stages which might not pass through the rolloffs are also checked. The same lamp additionally indicates overload occurring in the output stages after the Phase Sensitive Detector so that all possible locations and types of overload are monitored.

If the meter reading is off-scale when the Overload lamp is on, the nature of the overload is obvious and the gain of the instrument should be reduced. The Output Gain should be reduced a step at a time until the light goes out. If the light still glows after the X1 position is reached, the Sensitivity switch should be rotated clockwise.

Output overload can also occur with an on-scale meter reading. This can happen if the Time Constant is set too low to allow sufficient filtering of peak voltages from the Phase Sensitive Detector. The remedy is to simply increase the Time Constant setting, and/or switch from 6 dB/octave to 12 dB/octave.

Input overloads ahead of the signal rolloffs can only be eliminated by using a higher setting of the Sensitivity switch. Overloads at the input of the Mixer can be eliminated by either changing sensitivity and/or setting the signal rolloffs to obtain a higher degree of rejection of unwanted signals.

Overload recovery time can be significantly reduced by avoiding the use of the MIN. setting for the Low Frequency Rolloff switch.

SPECIAL CONSIDERATIONS

Grounding: The preamplifiers all have two means of rejecting unwanted signals due to ground-loop currents. The most effective property of the preamplifiers is their extremely high common mode rejection when using the A-B input mode; that is, almost total rejection of unwanted signals which appear at both inputs at the same phase and amplitude. The other property is a unique arrangement of the grounding of the preamplifier within the Model 126 mainframe.

A ground loop is a conduction path (Figure IV-15) around the signal ground and chassis ground. Current in the loop is caused, usually, by environmental electric and magnetic fields that cut the loop, the most notorious being at the power-line frequency. In addition to induced current, other sources of current are galvanic activity, slight differences of potential between the chassis grounds of the signal source and preamplifier, etc. This ground loop current develops voltage in the signal ground resistance and this voltage can be amplified along with the signal if steps are not taken to prevent this.

P.A.R. preamplifiers can greatly reject ground loop voltages even when operated with a single-ended input (A only, for instance). The preamplifiers have a 10 ohm resistor between the signal input BNC connectors' outer shells and chassis ground across which nearly the entire ground loop voltages appear. Amplification is with respect to signal ground (which is very nearly identical at each end of the shield of the cable because of this scheme) and ground loop voltages are thereby excluded to a large degree.

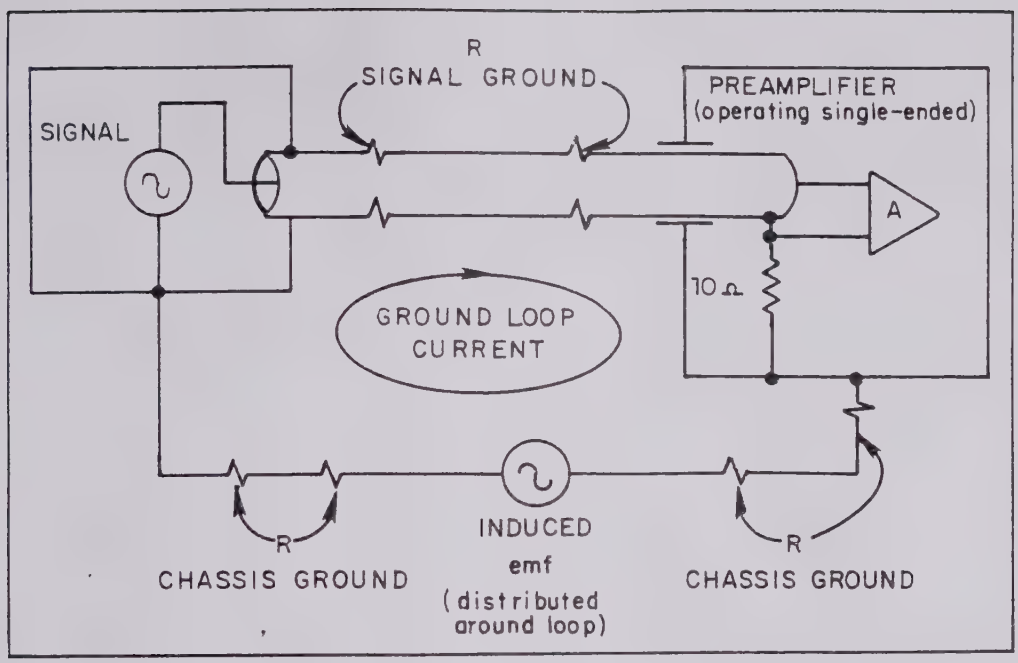


Figure IV-15. GROUND LOOP VOLTAGE REJECTION USING SINGLE ENDED INPUT

Figure IV-16 represents a typical situation using the differential inputs (A - B) of a preamplifier. With this connection, even the remainder of the ground loop voltage, which appears at equal amplitudes at both signal terminals, is rejected. The differential inputs are such that A is amplified with respect to B and not to ground. Since both inputs are very high impedance compared to the wires connecting them to the signal, there can be no current loops to cause the voltage at the preamplifier inputs to be any different than the voltage at the signal source.

Power Line Interference: Operation at the power line frequency is not recommended for low level measurements. Although much care has been taken with the internal design of the Model 126 and the preamplifiers (line frequency voltage due to internal power supply is less than 20 nV rms referred to the Direct inputs of a Model 116 Preamplifier) it is difficult to adequately shield the experiment's signal source to maintain such a low pick-up level. Operation at any harmonic frequency of the power line, from about the second through tenth, also requires more than usual care in shielding.

4.4 REFERENCE CHANNEL

MODES OF FREQUENCY CONTROL

INT/VCO: The frequency of the internal reference oscillator is set by a combination of the digital dials and the range switch. The digital dials may normally be set anywhere from 0.2 (which yields 20 Hz on the X100 band) to

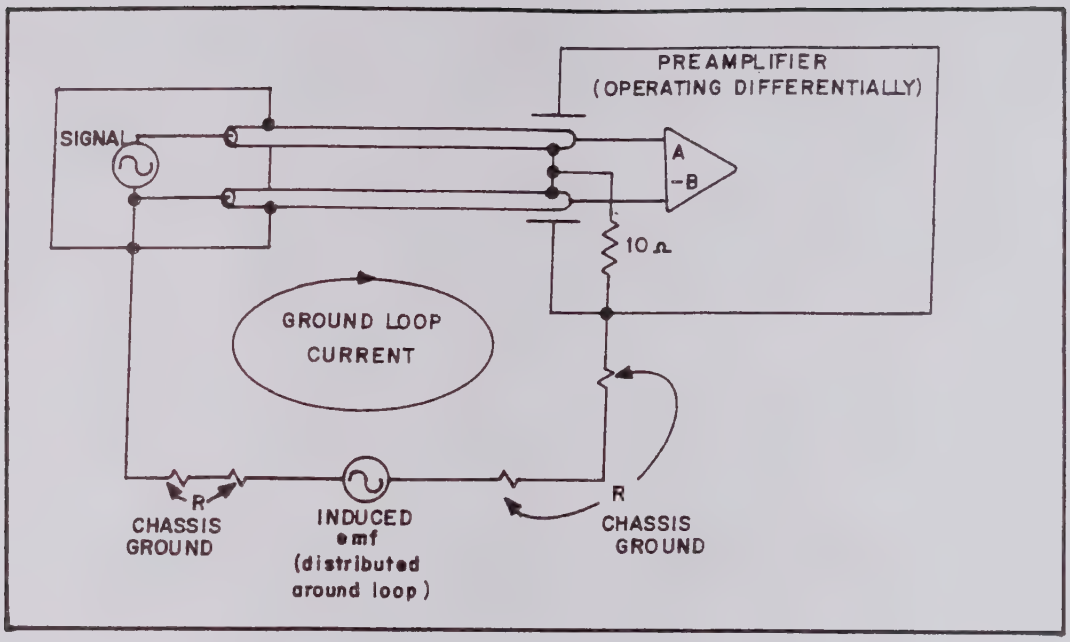


Figure IV-16. GROUND LOOP VOLTAGE
REJECTION USING DIFFERENTIAL INPUTS

10.0 (giving 1 kHz). In addition, an ADD 10 control which is concentric on the same band with the units dial can be used with the digital dials to effectively extend the range from 10.0 through 20.0. 1.5 kHz on the X100 band, for instance, is produced by setting the controls for 5.0 and ADD 10. Alternately, the X 1k band could be used with digital settings of 1.5 (NORM./ADD 10 switch set to NORM.).

The VCO method is operated in conjunction with the digital dials according to the following relation:

$$\text{frequency} = (\text{Digital Dial Setting} + 2 \times \text{VCO voltage}) \times \text{Band Setting} \quad (3)$$

The nomogram shown in Figure IV-17 can also be used to determine the effective dial setting which can then be multiplied by the band setting to arrive at the frequency.

Suppose it is desired to have the oscillator scan from 500 Hz to 1.5 kHz and back repetitively at a uniform rate of 10 Hz per second, what dial settings and input voltage would be required? One possibility would be to set the dials to 5.0, X100 and feed in a triangle wave which has peaks at 0 V and +5 V. When the triangle wave is at 0 V, a frequency of 500 Hz is obtained; when the triangle wave is at +5 V, it can be seen from Equation (3) that 1.5 kHz is produced. Since a 5 V change in the VCO input voltage causes a 1 kHz frequency change on this band, this change should be produced over a time of

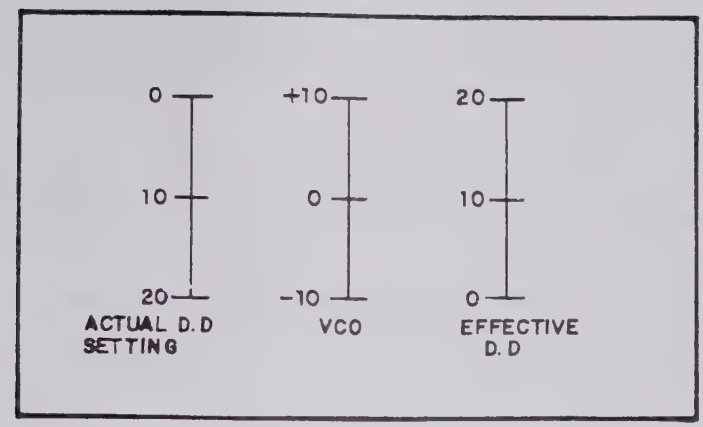


Figure IV-17. EFFECTIVE DIGITAL DIAL SETTING NOMOGRAM

100 seconds in order to achieve a 10 Hz per second slew rate so that the total period for the complete triangle wave should be 200 seconds.

EXT: A sophisticated tracking circuit automatically locks the internal reference oscillator to both the frequency and phase of an external waveform fed into the Reference Channel IN connector (see subsection 2.2, Specifications). This mode is used where experimental requirements necessitate that the Model 126 be locked to a signal arising in the experiment, as opposed to locking the external equipment to the Model 126 operating in the INT/VCO mode. The reference signal should be relatively noise free because, in the region of the zero crossings, any superimposed noise may cause many zero crossings to occur. As a result, the reference circuit momentarily 'sees' a higher reference frequency than intended and the frequency/phase lock can be lost. Frequently, moderately noisy signals can be cleaned up sufficiently for satisfactory operation by using a simple single-section low-pass filter.

The Reference Unlock lamp indicates that the tracking circuitry is not locked to the external frequency. Acquisition times vary according to the band setting and according to the difference between the external frequency and the frequency of the internal oscillator. Table II-2 in the Specifications section shows both the frequency range over which the tracking circuitry will perform well for each band and the maximum time to lock to the external reference. By operating in the INT/VCO mode for a moment at the approximate frequency of the external reference, the internal oscillator can be preset, greatly reducing the acquisition time when operating on the lower bands.

The frequency of the external generator must not change more rapidly than the Model 126 can track it (see Figure II-1). Provided the Reference Channel maintains a fixed frequency and phase relationship with the signal, detection is essentially the same as for fixed frequency signals.

It can be seen that there is considerable overlap of the frequency ranges of the bands. This often makes it possible to operate on either of two, or even three bands for a given frequency, e.g., 2.1 kHz on the X100, X1k, or X10k

band. If the external frequency changes rapidly, it may be necessary to operate on the highest band which covers that frequency since the slewing rate is very much greater on the higher bands.

In either of the external modes, there is no offset produced by a change in symmetry of the synchronizing input waveform no matter how great that change might be. Response of the Phase Sensitive Detector to harmonics is given in Table IV-1 on page IV-25 and is also not affected by any change in symmetry.

EXT. f/2: Operation of the Reference Channel in this mode is essentially the same as for the EXT. mode except the internal oscillator locks to twice the frequency of the external reference. The maximum input frequency in this mode is 105 kHz.

This mode makes it possible to immediately take direct measurements of signals at the second harmonic frequency of the external reference.

Special Considerations: Very high speed circuitry is employed in the external modes of operation in order to reduce the phase difference between the internal oscillator and the external reference to an absolute minimum even at the maximum operating frequency of 210 kHz. For this reason, some care should be taken to insure that the "frequency" actually fed into the Reference Channel is the desired frequency and not something higher. One way of inadvertently introducing additional crossings of the mean is to connect a waveform with very fast rise-fall times to the Reference Channel input without properly terminating the interconnecting cable. Improper termination could produce ringing which would be interpreted by the Model 124 as a higher frequency than the operator expected. Another way of introducing additional crossings of the mean is to allow interference from motors, light switches, or any spark generating electrical equipment to contaminate the external reference. Use of shielded cable to the Reference Channel input should prove helpful. Whenever possible, the level of the external reference should be several volts so as to be large compared to any unwanted interference.

PHASE CONTROLS

The high resolution potentiometer covering a range of 0 to 100 degrees in conjunction with the Quadrant switch determines the phase of the synchronous detection process with respect to the Reference Channel output (and input when using the external modes).

The Phase Sensitive Detector produces a dc output proportional to the component of the signal at the phase set on the controls. When the controls are adjusted for maximum meter indication, the phase of the signal can be read from the controls while the amplitude of the signal can be read on the meter.

Quite often, meter fluctuations due to noise cause difficulty in finding the setting which gives a maximum reading. When this is the case, it is normally more accurate to adjust for a null output which occurs when the controls are set at either plus or minus 90 degrees with respect to the phase of the signal. It is then a simple matter to switch to the adjacent quadrant which

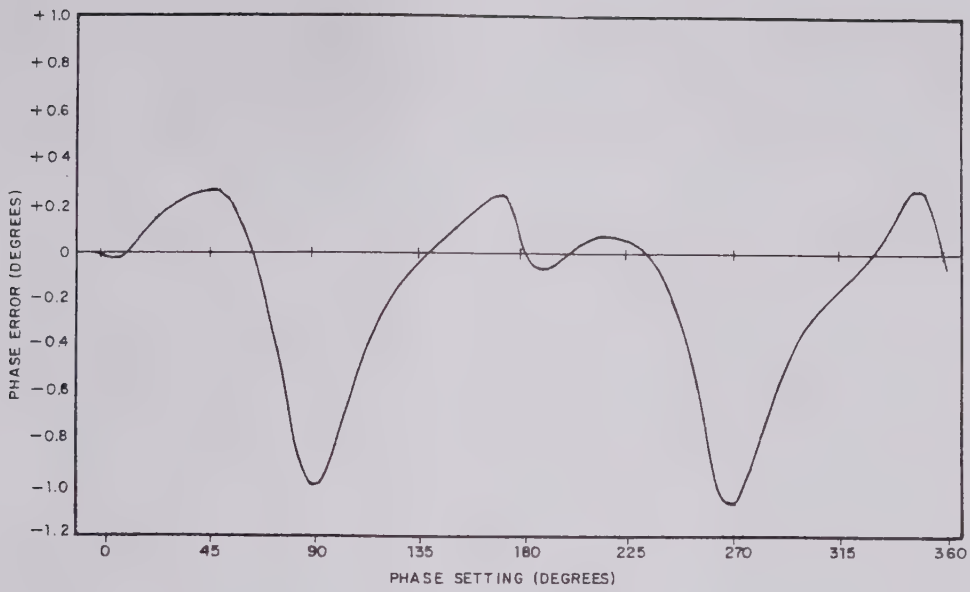


Figure IV-18. TYPICAL ACCURACY OF THE PHASE CONTROLS (20 Hz to 20 kHz)

yields the positive deflection on the meter and read the phase from the controls.

Absolute accuracy and resolution of the phase controls are described in the Specifications, subsection 2.2. Typical accuracy of the phase controls is shown in Figure IV-18. Beyond the frequency range given (20 Hz to 20 kHz) in the figure, the phase controls may not indicate the actual phase of the signal because of phase shifts introduced in the Signal Channel at extreme frequencies. Even at middle frequencies, it should be noted that the settings of the Low and High frequency Rolloff controls can have an effect on the phase of the signal. A calibration can easily be made at any frequency by connecting the preamplifier input to the reference drive at the experiment and adjusting the phase controls for a maximum output. The phase controls then indicate the net phase shift in both the Signal and Reference Channels. This shift is then subtracted from any experimental phase readings taken while operating at that particular frequency.

OUTPUTS

The Reference Channel OUT connector provides a sine wave output at the internal oscillator frequency. The amplitude can be varied from "zero" (actually a few microvolts minimum) to 1 volt rms by adjusting the logarithmically tapered Level potentiometer. The settings corresponding to various rms output amplitudes are marked on the front panel. The output impedance varies from about 1 kilohm to 1.6 kilohm depending on the setting.

Instruments with the Power Amplifier Option installed produce an output level of a factor of ten greater than that shown on the front panel, i.e., 0 to 10

volts rms. The output impedance is fixed at 600 ohms regardless of the setting of the Level control. A standard Model 126 can be converted to include the Power Amplifier Option by merely changing the Power Supply Board to one which has the Option installed on it. No chassis wiring changes are necessary.

4.5 PHASE SENSITIVE DETECTOR AND OUTPUT STAGES

FUNCTION-MODES OF OPERATION OF THE DETECTOR

Phase Sensitive Detector (PSD): When the Function switch is in any of the three PSD positions, the Model 126 operates as a Lock-In Amplifier. As stated in subsection 4.3, the Block Diagram and Front Panel Layout discussion, the detector convolutes the signal frequency in such a way that the output of the detector is the sum and difference frequencies of the signal and the reference. It can be seen then, that if the signal and the reference are at the same frequency, which is normal, one of the output frequencies of the detector is zero or simply dc. Noise or other interference is normally not exactly at the same frequency as the signal and therefore cannot produce zero frequency at the output of the detector. The dc which is produced is proportional to the amplitude of the in-phase component of the signal and is sent through the low pass filters of the Output Stages to drive the meter and the various output connectors.

There is no dc output produced by the component of the signal which is in quadrature phase with respect to the reference. The dc output due to a sine wave signal of amplitude A and with a phase difference ϕ with respect to the reference is related by the following:

$$\text{DC VOLTAGE} = A \cos \phi.$$

Since the phase of the reference drive to the detector can be independently varied by the front panel Phase controls, ϕ can be adjusted to any value.

To be more precise, the reference input to the detector is actually a square wave composed of a certain amplitude of fundamental frequency f, and lesser amplitudes of all the odd harmonics - third harmonic at 1/3 the amplitude, fifth harmonic at 1/5 the amplitude, seventh harmonic at 1/7 the amplitude, etc. Therefore, if the incoming signal has any odd harmonic components, the detector will also convert them to dc at its output, since their difference with respect to the corresponding harmonics of the reference is zero. However, because the detector's output is actually the product of its two inputs, the dc produced by harmonic signals is less than that produced by the fundamental. In fact, the response of the detector to the odd harmonic signals is only 1/3 for third harmonic signals and similarly smaller for the higher ordered harmonics.

Great care has been taken to minimize the detector's response to even harmonics. The typical harmonic response when operating with maximum Signal Channel bandwidth is shown in Table IV-1. Reducing the High Frequency Rolloff setting can significantly diminish the response to harmonics.

ACVM: When the Function switch is in the ACVM position, the Model 126 oper-

Harmonic	PHASE SETTING 0°	90°	180°	270°
2nd	0.15%	0.5%	0.2%	0.5%
3rd	35%	35%	35%	35%
4th	0.13%	0.55%	0.25%	0.7%
5th	15%	15%	15%	15%

Table IV-1. TYPICAL HARMONIC RESPONSE
OPERATING WITH MAXIMUM SIGNAL BANDWIDTH

ates as an ac voltmeter with certain advantages over a conventional acvm. For one, the voltmeter can be more frequency selective by adjusting the bandwidth of the Signal Channel Rolloff controls. Also, the meter response time can be easily adjusted over a wide range by use of the Time Constant switch permitting accurate measurements of fluctuating signals. The meter circuit has a "crest factor" (ratio of peak amplitude to rms amplitude) greater than five, allowing measurement of signals having small average and large peak amplitudes without overloading. The accuracy of the ACVM is ±1% from 2 Hz to 20 kHz, increasing to ±10% at 210 kHz; +0, -30% below 2 Hz.

Phase Meter Option: The Phase Meter Option, which may be switched on by a toggle switch on the rear panel, enables direct readout of the phase of any symmetrical input signal. The meter deflection is a maximum of plus or minus 90% of full scale on the X10 position of the Function switch, corresponding to the signal being exactly in-phase or exactly out-of-phase with the setting of the front panel Phase controls. For instance, if the Phase control is set to 90°, the meter will read the phase of the signal with respect to the Reference Channel Output with 0-to-90° lead presented linearly as 0-to-90% on the positive meter scale, and 0-to-90° lag presented on the negative meter scale.

Below 10 kHz, the Sensitivity switch can be set to 100 μV for all signal levels from a few microvolts to the overload point (which is monitored by the Overload Lamp) at approximately 70 mV. At higher frequencies, better results can be obtained by setting the Sensitivity switch to the approximate level of the input signal. In any case, the meter indication is relatively unaffected by amplitude. At midrange frequencies, for example, the phase indication on the 10 mV setting of the Sensitivity switch is nearly constant with input levels ranging from about 50 μV to 70 mV, assuming, of course, that the phase of the signal is held constant at all levels.

OUTPUT GAIN/NONCOHERENT SIGNAL OVERLOAD

When operating the Model 126 as a Lock-In Amplifier, i.e., in one of the PSD positions of the Function switch, the least amount of Output Gain should be employed. The actual full scale Sensitivity is affected by the Output Gain

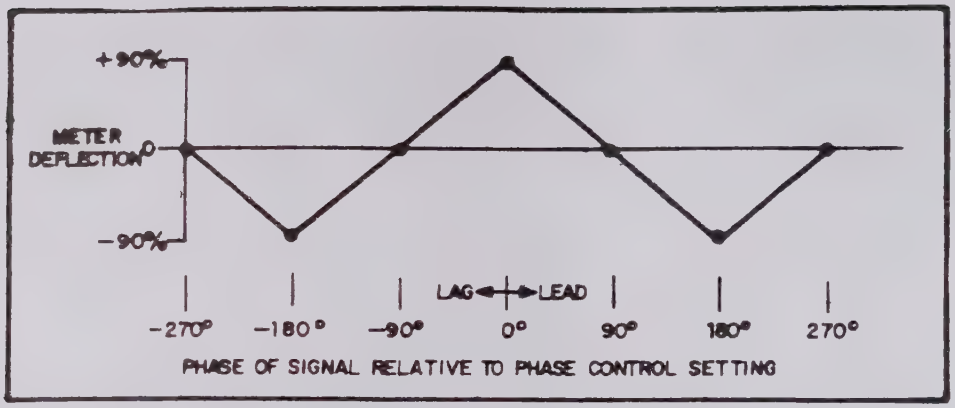


Figure IV-19. METER INDICATION AS A FUNCTION OF PHASE DIFFERENCE BETWEEN INPUT SIGNAL AND PHASE CONTROL SETTING

setting so that, for example, 1 mV full scale can be obtained by setting the Full Scale Sensitivity switch to 1 mV and the Output Gain to X1, or by setting the Full Scale Sensitivity switch to 10 mV and the Output Gain to X10, or finally, by using settings of 100 mV and X100 (all settings based on use of a Model 117 Preamplifier).

This ability to manipulate the distributed gain in the instrument has been incorporated in the design so that the performance can be made optimum for various signal-to-noise ratio conditions of the incoming signal. For relatively clean signals, where the noise and other noncoherent voltages are not greater than three times the required full scale sensitivity, the X1 Output Gain setting can be used. This results in an extremely stable output zero since the temperature dependent drift of the dc amplifiers has minimal amplification. If the signal is very small compared to the noncoherent voltages, lowering the Full Scale Sensitivity switch so as to obtain a greater meter deflection may result in overload of the ac amplifiers in the Signal Channel. In this case, the use of a higher Output Gain will boost the dc output of the instrument and, thus, the meter indication, without causing the Signal Channel to overload. The drift in the dc amplifiers will be magnified, however, so that the output zero will not be as stable under this condition. The relation between Output Gain, stability, and overload capability is given in subsection 2.2, Specifications.

The Model 126 tolerates noncoherent signals unusually well. The presence of large nonsynchronous signals produces only a slight shift in the output zero of the Lock-In Amplifier as shown in Figure IV-20.

OUTPUT FILTER MODES - TIME CONSTANTS AND INTEGRATOR

The conventional function of the Output Stages is to operate as a low pass filter, rejecting all components at the output of the Detector except the dc voltage (which is proportional to the in-phase component of the signal of interest). The Output Stages of the Model 126 have the additional capability of performing a true integration of the Detector's output. A Normal/Hold switch and a pushbutton Reset switch provide full control of the Output Filter in either the Low Pass Filter or the True Integrate mode.

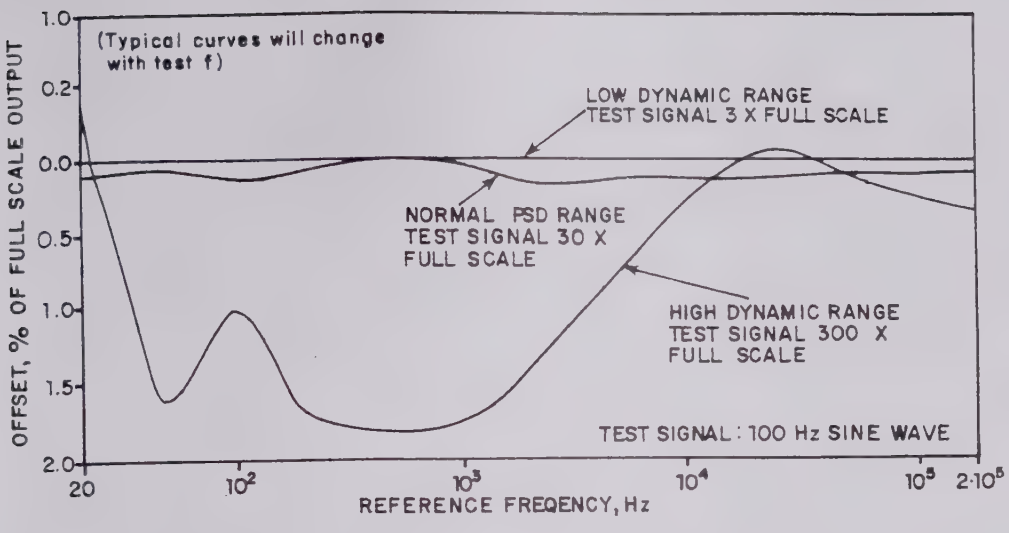


Figure IV-20. OUTPUT OFFSET DUE TO NONSYNCHRONOUS SIGNALS

Low Pass Filter: The filter can be operated either single section with a 6 dB/octave rolloff rate, or double section with a 12 dB/octave rolloff rate as selected by the inner concentric knob on the Time Constant switch. The outer knob sets the time constant of each section simultaneously with a range of 1 ms to 300 s plus MIN. (slightly less than 1 ms) and EXT. which permits the use of external capacitors to determine the time constant.

The Time Constant switch should be set so that the output, as read on the meter or on an external monitor, is as noise-free as required. In general, signals which are contaminated by large amounts of noise near the signal frequency require larger time constants. In many cases, where the characteristics of the noise are known for frequencies near the signal frequency, the noise voltage referred to the input can be determined for any given time constant by one of the following relations:

$$E_n = e_n \sqrt{\frac{1}{4TC}} \qquad \text{for 6 dB/octave}$$

$$E_n = e_n \sqrt{\frac{1}{8TC}} \qquad \text{for 12 dB/octave}$$

where e_n is the noise voltage at input in volts/$Hz^{\frac{1}{2}}$,
TC is the Time Constant in seconds, and
E_n is the output noise in volts referred to the input.

The term inside each radical is referred to as the "equivalent noise bandwidth" or ENBW of the Low Pass Filters.

For example, suppose that a 1 mV signal is being measured with the controls set for a 1 mV full scale sensitivity. Also suppose that 10 mV of noise, occurring over a frequency range which includes the signal frequency, is present at the input. If it is known that the noise has a characteristic value of, say, 100 $\mu V/Hz^{\frac{1}{2}}$ in the region near the signal frequency, the effect of this can be readily calculated. Using a typical setting of 6 dB/octave and a

time constant of 1 s, the above equation gives the following:

$$E_n = \frac{100\ \mu V}{\sqrt{Hz}} \sqrt{\frac{1}{4(1s)}} = 50\ \mu V\ rms$$

A considerable improvement in the signal to noise ratio is clearly evident. The signal to noise ratio at the input is, of course, 1 mV:10 mV or 1:10. After processing, the noise is reduced to a level of 50 μV referred to the input for an effective signal to noise ratio of 1 mV:50 μV or 20:1. The improvement is a factor of 200 by simply introducing a one second time constant in the signal path!

As shown in Figure IV-21, the 6 dB/octave filter exhibits a 3 dB attenuation at $1/2\pi TC$ on the frequency axis. On the time axis, it has a step-function response of $1 - e^{-t/TC}$ seconds. The rise time from 10% of full amplitude to 90% of full amplitude is 2.2 TC, and from 0% to 95% is 3 TC.

Also as shown in Figure IV-21, the 12 dB/octave filter has a 6 dB attenuation at a frequency equal to $1/2\pi TC$. On the time axis, it has a step-function response of $1 - (1 + t/TC)e^{-t/TC}$. The rise time from 10% to 90% of full amplitude is 3.3 TC, and from 0% to 95% is 4.8 TC.

External Time Constant: For special intermediate values of time constant or for values in excess of 300 seconds, place the Time Constant switch in the EXT. position and connect a pair of capacitors of equal value between pins 8-9 and 10-11 of the rear panel octal socket. To determine the time constant for this external mode, multiply the single capacitor value (in Farads) by 30 megohms. The capacitors should be low-leakage film types (mylar, polycarbonate, polystyrene, or teflon, but not electrolytic or tantalum) rated at 25 volts or higher.

Integrator: Placing the inner concentric Time Constant control to the center position enables the Output Stages to integrate the output voltage from the Detector with respect to time with the following characteristics:

$$E_{out} = \frac{1}{TC} \int_0^t E\ dt = \frac{1}{TC}\ Et,$$

where E is the voltage which would be obtained if the Lock-In Amplifier were used in the more conventional mode with the output stages operating as simple dc amplifiers rather than as an integrator. That is,

$$E = \frac{\text{input signal voltage x cos } \emptyset}{\text{Full Scale Sensitivity}}$$

$\emptyset$ is the phase of the signal with respect to the phase of the reference drive to the detector.

In plain language, the equations indicate that if the Model 126 is operated as a conventional Lock-In Amplifier measuring a signal which is say, 10% of full scale, the same output indication, 10% of full scale, would be obtained

by operating in the Integrate mode for a period of time equal to one time constant. If the integration time were made equal to 5 time constants, then the output indication would be 50% of full scale. The integration time can be controlled by releasing the Reset pushbutton at time t = 0 and then placing the Normal/Hold switch to Hold at the end of the desired time. If the input amplitude varies during the integration time the final voltage is based on the average signal amplitude multiplied by the number of elapsed time constants.

OUTPUTS

The final dc output voltage, after all processing, is available at a front panel BNC connector located near the Function switch. Plus or minus 10 volts dc corresponds to plus or minus full scale; the output impedance is 1 kilohm. The same voltage, through a separate 1 kilohm impedance, is also available at the rear panel Recorder binding posts. Loading either output will not affect the voltage at the other, nor will it affect the meter indication.

4.6 PHASE METER OPTION (126/99)

INTRODUCTION

A Model 126 equipped with this option can be operated either as a normal Lock-In Amplifier or as a Phase Meter, depending on the position of the rear-panel NORMAL/PHASE switch.

When operated as a phase meter, the input signal, after some initial ac gain, is routed through an amplifier limiter having a constant amplitude (clipped) rectangular output. This signal, when synchronously demodulated, yields a dc output that is a linear function of the phase difference between the reference and input signals. The output gain/sensitivity is 9 V out corresponding to 90° or 100 mV per degree with the Output Expand switch set to X10. With the output expand switch set to X100, the sensitivity is increased to 1000 mV/°.

For best phase meter performance at frequencies below 10 kHz, the Sensitivity switch should be rotated counterclockwise until the Overload indicator lights, and then adjusted clockwise one position.

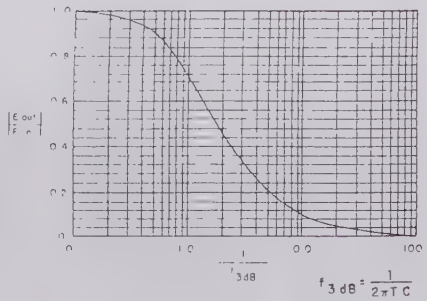
At frequencies above 10 kHz the input signal should not exceed thirty times full scale (sinewave rms to selected sensitivity), with the additional restriction that the input signal should not exceed 300 mV rms for Sensitivity settings of 100 microvolts through 100 mV. On the 200 mV and 500 mV Sensitivity switch ranges, the input signal should be at least 20% of the selected sensitivity, but no greater than 500 mV (sinewave rms).

ALIGNMENT PROCEDURE (to be performed after entire instrument is aligned)

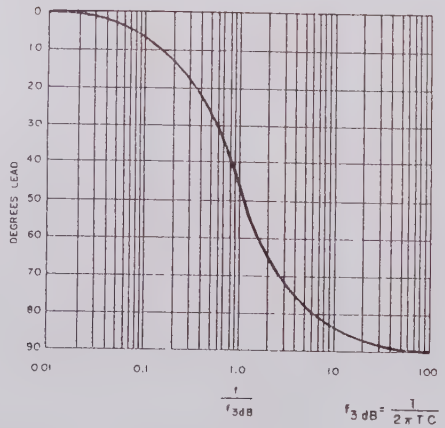
(1) Obtain the following equipment

(a) General purpose oscilloscope capable of making true-differential measurements. Standard 10:1 probes should be used.

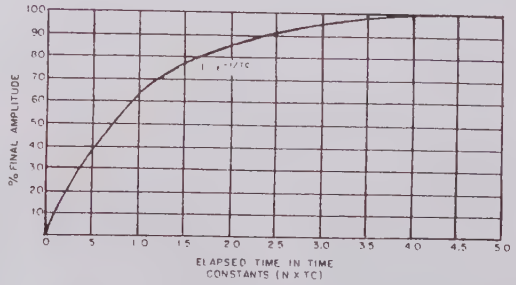
(b) General purpose digital voltmeter (three digits).



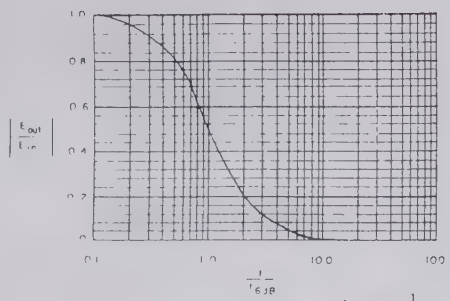
6 dB/Oct. Amplitude Transfer



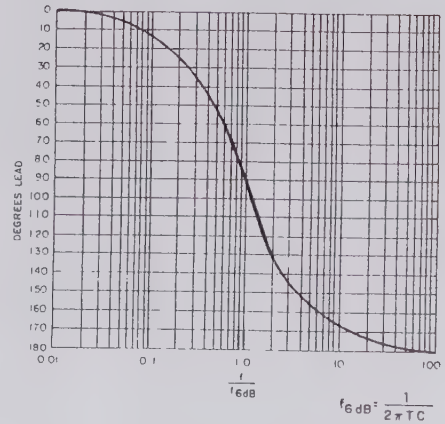
6 dB/Oct. Phase Transfer



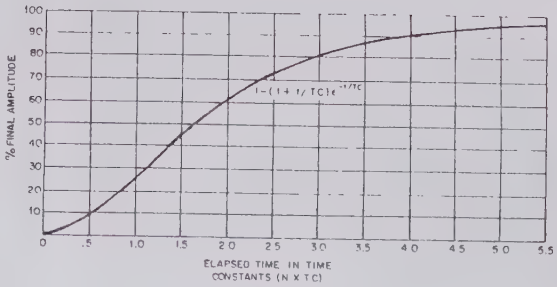
6 dB/Oct. Step-Function Response



12 dB/Oct. Amplitude Transfer



12 dB/Oct. Phase Transfer



12 dB/Oct. Step-Function Response

Figure IV-21. OUTPUT FILTER TRANSFER FUNCTIONS

(2) Remove the top cover. Then turn on the power and allow a fifteen minute warmup.

(3) Set the Model 126 controls as follows.

Input Selector (Preamp)	A
Sensitivity	100 mV
L.F. Rolloff	MIN.
H.F. Rolloff	MAX.
Reference Frequency Controls	NORM, 4.0, X100 (400 Hz)
Reference Mode	INT.
Reference Level	100 mV
Phase switch	270°
Phase dial	90.0°
Time Constant controls	300 ms, 6 dB/OCT.
Zero Offset	
dial	fully counterclockwise
switch	center position (OFF)
Function	ACVM
NORM/HOLD switch	NORM.
NORM/PHASE switch (rear panel)	PHASE

(4) Connect a BNC cable from the Reference Channel OUT connector to the Preamplifier "A" Input.

(5) Connect an oscilloscope, dc coupled, to pin 9 of the Phase board. NOTE: Observing the instrument from the front, this board is located against the left bulkhead towards the rear.

(6) The signal observed at the oscilloscope should be a 400 Hz square wave. Rotate the front-panel Reference Level control counterclockwise as required to make the squarewave noisy.

(7) Adjust the A2 DC control (located on the Phase board) for best symmetry in the observed square wave. When best symmetry is obtained, try further reducing the Reference Output amplitude and repeat the symmetry adjustment. Repeat these two steps until no further improvement in the setting of the symmetry adjustment can be made.

(8) Before proceeding, return the Reference Level control to a setting of 100 mV and check at pin 5 of the Phase board for a sinewave output with an amplitude of approximately 3 V pk-pk. Then set the rear-panel NORM/PHASE switch to NORM.

(9) Connect the DVM (digital voltmeter) to the FUNCTION OUT connector.

(10) Disconnect the wires going to pins 1 and 2 of the Phase Board. Then jumper the two wires together with a clip lead.

(11) Adjust the front-panel Reference Level control for a DVM reading of about 9.00 V. Record the exact reading obtained.

(12) Remove the jumper connecting the leads earlier removed from pins 1 and 2. Then reconnect these leads to pins 1 and 2. The DVM reading should decrease a few percent due to loading effects.

(13) Adjust trim-potentiometer R1003, located on the Signal Amplifier board, to restore the DVM indication to the reading recorded in step 11.

(14) Set up the oscilloscope for differential operation. Use two BNC cables terminated in alligator clips for the input leads instead of 10:1 probes. Connect one input to pin 5 of the Phase board (shield to ground) and the other input to that end of R3130 (3.3 kilohm resistor on the Mixer board) which is in common with the emitter of transistor Q3109.

(15) Adjust the A1 GAIN trim-potentiometer (located on the Phase board) for minimum observed differential signal. It should be possible to get the signal amplitude down to less than 3 mV pk-pk. (If not, check the CMR of the oscilloscope before suspecting the Model 126)

(16) Disconnect the oscilloscope from R3130 but leave it connected to pin 5. Set up the oscilloscope to display the pin 5 signal (single ended).

(17) Set the NORM/PHASE switch (rear panel) to PHASE. Then set the Function switch to X10.

(18) Observing the oscilloscope, adjust the front-panel REF. LEVEL control until the amplitude of the monitored signal is just high enough to cause both negative and positive clipping.

(19) Adjust the CLIPPING SYMMETRY trim-potentiometer, located on the Phase board, for symmetrical clippling of the observed signal. Then remove the oscilloscope.

(20) Connect the DVM to the front-panel FUNCTION OUT connector. Then adjust the A2 AMPLITUDE trim-potentiometer, located on the Phase board, for a DVM indication of 9.00 V.

(21) Carefully set the front-panel Phase dial for peak DVM indication. Then readjust the A2 AMPLITUDE trim-potentiometer for the desired 9.00 V reading.

This completes the Phase Board alignment.

4.7 REFERENCE POWER AMPLIFIER OPTION (126/97)

The normal Model 126 provides a reference output amplitude of 1 V rms which is adjustable by the front-panel Reference Level control. With the Power Amplifier option installed, an internal amplifier is added that increases the Reference Output amplitude (max) to 10 V rms at 600 ohms.

4.8 SELECTIVE EXTERNAL REFERENCE MODE OPTION (124A/77)

In some applications, it may happen that the reference signal produced by the experimental apparatus is of very poor quality, that is, it is accompanied by much noise and interference. As explained previously, a sinple low-pass filter in series with the reference signal will usually clean up such a signal sufficiently to make it acceptable to the Model 126 reference circuits. Nevertheless, there could arise situations where this relatively simple technique would prove inadequate. If this is the

case, the best one can do is to pass the reference signal through a tuned bandpass filter of moderate Q, perhaps 10. Even the poorest reference waveform, once it has been passed through such a filter, will be good enough to allow normal reference channel operation. The tradeoff made in using such a filter is that, for all practical purposes, the tracking capability of the Reference Channel is lost. Any change in the frequency of the reference signal results in amplitude loss and phase shift as the frequency moves out of the center of the passband.

Such a filter can, of course, be connected externally. However, in the case of a Model 126 equipped with the Selective External Reference Modification, a Q-of-10 filter is provided internally. These units are equipped with a rear-panel switch that allows the selective external (tuned) reference mode to be selected. With the switch in the NORMAL position, the instrument works exactly as described previously. With the switch in the SEL. EXT. position, the instrument operates in the Selective Reference mode providing the front-panel Reference Mode switch is set to INT/VCO. If the front-panel Reference Mode switch is in any other position when the rear-panel switch is set to SEL. EXT, improper Reference Channel operation results.

The only other consideration in using the Selective External Reference mode is to tune the Reference Channel to the frequency of the input reference signal. This is easily done by applying the reference signal and then monitoring the amplitude of the signal at the Reference OUT connector with the Signal Channel.

A suitable procedure follows.

(1) Set the controls as follows.

Power	ON
Sel. Ext. switch (rear panel)	SEL. EXT.
L.F. ROLLOFF	MIN
H.F. ROLLOFF	MAX
Reference Level	1 V (100 mV if Ref. Power Amp option is installed)
Function switch	ACVM
Sensitivity	500 mV
Signal Input switch	A

(2) Set the Reference Frequency controls to the appropriate frequency of the Reference signal.

(3) Connect the Reference signal to the REF. IN connector. NOTE: The amplitude of the Reference signal should be in the range of 100 mV pk-pk to 3 V pk-pk.

(4) Connect a cable from the REF OUT connector to the "A" Input connector of the preamplifier. The panel meter should show some deflection. If it does not, adjust the Reference Frequency controls as required to obtain some deflection and then further adjust them for maximum meter indication. If the meter indication exceeds full scale, use the Reference Level control to reduce the indication to about 50% of full scale. Then readjust the Reference Frequency controls for the desired maximum indication.

This completes the tuning procedure. The internal bandpass filter is now tuned to the reference frequency. The cable interconnecting the REF. OUT connector and the "A" Input of the Preamplifier can now be removed and the instrument operated in the usual manner, bearing in mind that, if the reference frequency is changed, retuning will be required.

4.9 PHASE, LEADING OR LAGGING

In addition to being able to measure the amplitude of very low level and noisy signals, lock-in amplifiers can also be used to measure the phase between the input signal and the reference drive signal. Sometimes, however, an operator is not only interested in the magnitude of the phase difference, but wants to know specifically whether the input signal is leading or lagging with respect to the reference. There is also the case where a phase shift between the input and reference signals takes place after the initial measurement, with the result that the Phase controls have to be re-adjusted to maintain the peak indication. When this happens, it may be important to know whether the phase shift was in the leading direction or in the lagging direction.

To measure phase with a Model 126, the Phase controls are adjusted to obtain a positive peak indication, the same as for an ordinary amplitude measurement. When a positive peak is achieved, the Phase controls will indicate the number of degrees by which the input signal leads the reference. If the angle is greater than 180°, it may be more convenient to subtract the indicated angle from 360° and state the difference as the angle by which the input signal lags the reference. NOTE: Any internal phase shifts must be taken into account.

The problem of determining the direction of a phase shift is more complicated, but only slightly so. Assume a peak has occurred (either polarity), and at some later time a phase shift occurs with a resultant loss in peak indication. To determine the direction of the phase shift, simply re-adjust the Phase controls to restore the peak indication, and while so doing, note whether the new phase setting is higher or lower than the old one. If the new phase setting is higher, the phase shift of the signal relative to the reference was in the leading direction. If the new phase setting is lower, then the shift was in the lagging direction.

SECTION V
THEORY AND CIRCUIT DESCRIPTION

5.1 INTRODUCTION

The theoretical aspect of this section concerns the individual circuit functions and not the theory of the operation of the system as a whole. The overall description of Lock-In Amplifier theory is covered by subsection 4.2. A perspective on the location of the circuits detailed in this section can be obtained by referring to the complete Block Diagram on page IX-2.

5.2 POWER SUPPLIES

The ac and unregulated dc supplies are illustrated on both the Chassis Wiring Diagram, page IX-19, and the Block Diagram, page IX-2. Note that either 115 V or 230 V, 50-60 Hz, is routed through the line fuse, power switch, and Line Voltage Selector switch to the split primary windings of the power transformer. For 115 V operation, the two primary windings are in parallel. For 230 V operation, they are in series. The secondary output is applied across a rectifier bridge to obtain unregulated plus and minus 31 V. This unregulated dc is supplied to the regulators shown on the Power Supply Schematic, page IX-15.

There are two regulators. The first takes -31 V from the rectifiers and regulates it to -24 V. Zener diode CR6009 establishes the reference and trim-potentiometer R6028 allows the output level to be accurately set. Regulation is achieved by high gain amplification of any difference voltage between the reference zener and the wiper of the trim-potentiometer. The first stage of this amplification is the differential amplifier composed of Q6009 and Q6010 along with the associated passive components. The output of the first stage is further amplified by a second differential amplifier which includes Q6006 and Q6007. The amplified difference voltage is then buffered by driver transistor Q6008 and applied to the power pass transistor. The pass transistor is thereby controlled in such a way as to keep the original difference voltage zero and thus maintain the output at a constant -24 V regardless of load.

The second regulator similarly takes the +31 V output of the rectifiers and regulates it to +24 V. Note that the reference for this regulator is the -24 V regulated output of the first circuit, and that the output level of the +24 V regulator is determined by the setting of R6010. The internal operation is essentially identical to that described for the first regulator.

Three fuses protect the power supply circuitry. Two of these, F6000 and F6001, are 1/2 ampere, fast-blow fuses in the plus and minus unregulated 31 V lines. The third, F1, is a 1/2 ampere (115 V) or a 1/4 ampere (230 V) slow-blow fuse in the ac line before the Power switch.

5.3 PREAMPLIFIERS

MODEL 116

The heart of the Model 116 is a high input impedance, differential amplifier

with exceptionally low internal noise and very high common mode rejection ratio. The A-B input signals in the DIRECT mode are applied to the gates of the dual monolithic JFET Q108-Q109, which forms a differential amplifier. The balanced output from the first amplifier is buffered by Q104 and Q107 and fed into a second differential amplifier which includes Q105 and Q106. The collector output current from Q105 is passed through common base connected Q110 to the input of the Current Reflector circuit Q113. The Current Reflector's output is simply a current equal in magnitude to that which is fed into it but opposite in phase. Thus, the two outputs of the second differential amplifier, the collector of Q106, and the collector of Q105, are combined inphase and applied to the emitter-follower Q114, whose output drives the Signal Channel amplifiers in the Model 126.

The required gain of 5 or 50 (switched by relay K100) is far less than the gain of the combined differential amplifiers described in the previous paragraph. Negative feedback from the output to the sources of the JFET via R129 reduces the closed loop gain to the selected amount. This technique eliminates any distortion or gain instability which might appear in the individual amplifiers and places the dependence for linearity and gain stability on the feedback resistors themselves, which, of course, are excellent in this respect.

To obtain a very high common mode rejection ratio, the operating currents and voltages of the amplifiers are maintained at constant values regardless of the incoming common mode voltage through the action of Q100-103 and Q112.

Constant current source Q101 causes a fixed voltage to develop across R108 (10 V) and across the additional resistor network (10 V) composed of R125, R127 and R128 from the bottom of R108 to the sources of the JFET. These voltage drops are used as references to regulate the positive power supply voltage for the preamplifier itself and to regulate the total current through the JFET. The differential amplifier, Q102 and Q103, which senses the voltage at the emitters of Q105 and 106, adjusts the standing current in the JFET by controlling Q112. Since the standing current determines the voltage drop across the drain load resistors, R103 and R105, it therefore adjusts the voltage level at Q105 and Q106 to equal that at the bottom of R108. The positive power supply voltage is slaved to the top of R108 by the action of emitter follower Q100. R136 is adjusted to insure that the regulating current through the JFET splits identically between the two sources to further improve common mode rejection. C109 balances the high frequency characteristics to maintain good common mode rejection at these extended frequencies.

Transformer: In order to obtain a low noise figure when amplifying signals from low source impedances, T1 can be switched in. A discussion of the transformer's characteristics can be found in subsection 4.3.

MODEL 117

The Model 117 is in every respect identical to the Model 116 except that, lacking a signal transformer, it can only be operated in the DIRECT mode.

MODEL 118

This preamplifier employs twenty PNP bipolar transistors selected for low

noise and connected in two sets of ten transistors in parallel. The signal source resistance for optimum noise figure is thus shifted down to one-tenth of the source resistance which would be optimum for a single transistor. Circuit analysis is otherwise the same as though only two single transistors were used. Q101 through Q110 and Q111 through Q120 are connected as an ordinary differential amplifier with emitter degeneration. Their collector signal currents, instead of developing signal voltage drops across conventional collector load resistors, are fed into a current sink much like the summing junction of an operational amplifier. Any signal current which passes through the common base stage Q121 and Q122 develops a voltage which is amplified with high gain by differential amplifier Q123 and 124 and buffered by emitter followers Q125 and Q126.

The output voltages thus present at the one end of R117 and R119 almost entirely cancel the signal currents from the collectors of the input "pair" of transistors. The output voltage can be readily determined once the magnitude of the signal currents is known. In this case, the currents are equal to the input voltage divided by the emitter degeneration resistance, that is, R112 plus the 50 ohms which is internal to the input transistors. The result is a gain of fifty when K100 is open, and a gain of 500 when K100 is closed.

Several steps have been taken to assure extremely high common mode rejection. Q100 delivers a constant current through the input pair regardless of the instantaneous common mode input voltage. Q121 and Q122, which serve as a common base circuit for the output stage, also function as emitter followers to bootstrap the collector voltage of the input pair at a level which is always 5 volts negative with respect to the emitters of the input pair. The fixed 5 volt reference for the emitter followers is developed by the constant current from Q127 developed across R113 and R114. The input pair is then maintained at constant operating current and voltage conditions in the presence of common mode input voltages.

Common mode voltages cannot appear at the output itself because of the action of differential amplifier Q129 and Q130. The mean voltage of the two balanced outputs (only one is used to drive the main-frame) is held to zero since any error is amplified and applied to emitter follower Q128. Voltage changes at Q128 affect the common mode current at the "current sinking" point previously described and thus adjusts the output common mode voltage to zero.

MODEL 119

The Model 119 differs from the Model 116 only in that the transformer characteristics are optimized for higher frequencies.

5.4 SIGNAL AMPLIFIER BOARD

The Signal Amplifier Board contains all Signal Channel circuitry between the preamplifier and the last stage of ac amplification which is located on the Mixer Board. A1001 contains a high gain differential amplifier Q1101 and Q1102 with full negative feedback from its buffered output (emitter follower Q1103) so that the resultant closed loop gain is almost exactly one and its output impedance is nearly zero ohms. R1007, in conjunction with one of the switch selected capacitors, C1005 through C1011, forms a high frequency roll-

off which is 3 dB down at the frequency set at the front panel. The total value of R1010 plus R1011 combined with one of the selected capacitors C1012 through C1019 provides a low frequency rolloff which is 3 dB down at the frequency set at the front panel.

A1002 is an operational amplifier connected as a non-inverting amplifier with gains of 5.4, 13.5, or 27.0 as selected by the portion of the Sensitivity switch attached to R1008 and R1009. The input to A1002 by way of another portion of the Sensitivity switch is from one of the output taps on the attenuator formed by R1010 and R1011. The output signal is similarly fed to the Mixer Board from one of the taps on the output attenuator R1015 and R1016. The remaining portion of the Sensitivity switch controls the relay-switched gain in the Preamplifier.

Within A1002 itself, Q1201-Q1202 constitutes the input pair. Q1203 provides a constant operating current for the input pair. Q1204 and Q1205 provide additional gain with the output of this stage driving Q1207. Collector load resistor R1208 is bootstrapped by the output to present an effective high load impedance to Q1205. Q1206 supplies an adjusted current to operate Q1207.

5.5 REFERENCE OSCILLATOR

Block Diagram: The Reference Oscillator is actually a dual integrator circuit arranged with limited positive feedback to cause it to oscillate. The schematic shown on page IX-9 can be reduced to Figure V-1. The integrators are each composed of a current output from a multiplier circuit fed into a capacitor. The output current of the multiplier is equal to the sum of the input currents multiplied by the second input of the multiplier. The second input is a current proportional to the output voltage of A3, an operational amplifier at the bottom of the diagram. Since this voltage, in addition to the capacitors selected by the Frequency Range switch, governs the frequency of oscillation, the entire circuit may be considered a Voltage Controlled Oscillator (VCO).

The sine wave voltage which appears on the capacitors is buffered by the two operational amplifiers with balanced outputs. Ignoring for the moment the small currents through the Limiter circuit and R4004, the input current of each multiplier depends on the output voltage of the preceding buffer, producing a current through R4002 or R4016 as the case may be. The multiplier input may be considered a current-sink at ground potential. At the operating frequency the circuit values have been chosen so that the voltage gain from the sine wave output of a buffer to the output of the following integrator is one-half; however, a phase lag of 90° is introduced. The buffer amplifiers each have a voltage gain of two (positive sign for upper output and negative for the lower).

The nominal amplitude of the sine wave at the four outputs, 0, 90, 180, and 270 degrees, is one volt rms. By following any one of these sine waves around the complete circuit, it can be shown that the closed loop gain is one, which is inherently true of any oscillator operating at a constant amplitude. The sine wave at the 180° output, for example, passes through the integrator at the left-hand end of the diagram, causing a sine wave at half

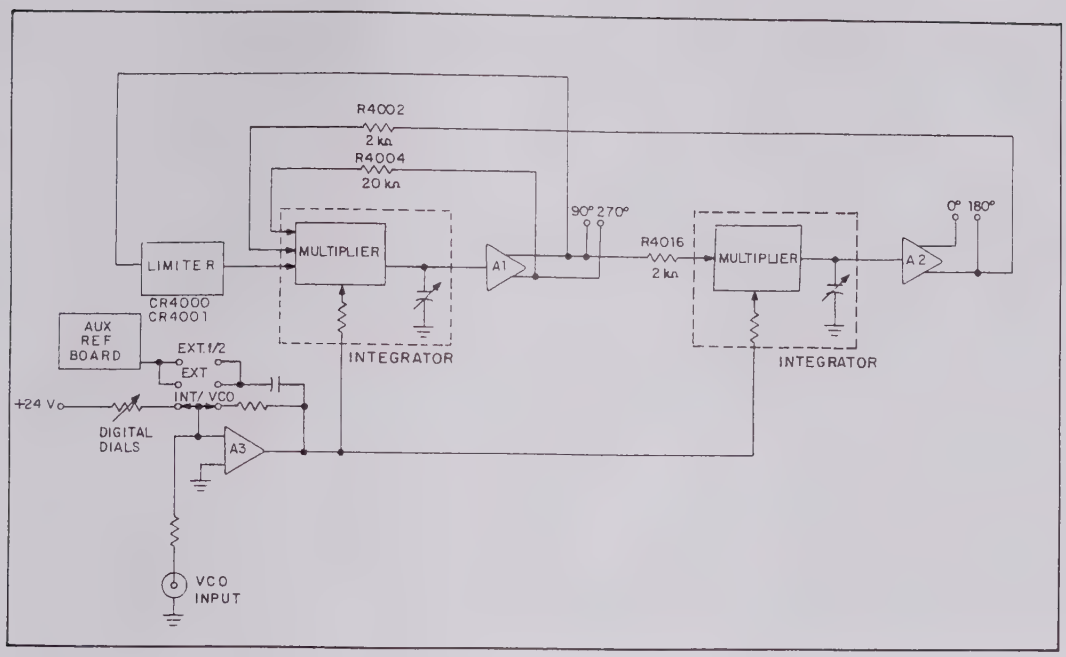


Figure V-1. REFERENCE OSCILLATOR BLOCK DIAGRAM

amplitude, and lagging 90° behind the phase at the input of the integrator, to appear at the input of A1. The phase at the input of A1 is therefore 90° The level is restored to 1 volt rms at the outputs of A1. The non-inverted (upper) output of A1 is, of course, also 90°. This now enters the second integrator where it emerges at one-half volt and at 0° to drive the input of A2. As before, the non-inverting output of A2 increases the level to one volt rms without changing the 0° phase. The inverting output is therefore one volt at 180° which was the original starting point in this analysis.

All that remains to be explained from a block diagram standpoint is how the one volt rms level is established and what determines the frequency. The previous paragraph followed a signal around the loop and it was found that the total loop gain was one at the oscillation frequency. For a given input voltage from A3, the multiplier will have a "constant current transfer ratio". Since the gain of an integrator is inversely proportional to the frequency, there will be some maximum frequency beyond which the gain around the total loop will be less than one and, therefore, no oscillation can exist above this maximum frequency.

At some lower frequency the gain around the loop must be greater than one and the circuit would oscillate with ever increasing amplitude except for the action of R4004. The sum of the 270° current through R4004 and the 180° current through R4002 produces a resultant which lies at some intermediate angle which leads slightly with respect to the 180° current. The phase lead through the remainder of the loop must therefore increase, causing the phase of the resultant to lead by a still greater amount. This regenerative phase in-

crease is actually an increase in the frequency of oscillation. (Frequency is simply the rate of change of phase and this is being increased as the wave circulates around the loop.) Once the frequency reaches the point where the gain of the loop is one, the action of the Limiter must be considered.

The current from the Limiter is of opposite phase with respect to the current into the integrator from R4004 and an exact cancellation occurs when the level at the 270° output is one volt rms. If the level is greater than one volt, the resultant of these two currents at the input of the integrator, combined with the 180° current through R4002, has a phase angle which causes the frequency of oscillation to escalate as previously described. The frequency rises into the region where the loop gain is less than one and the amplitude oscillation will automatically decrease until such cancellation is achieved. If the level falls below one volt, the resultant lags slightly behind 180° and the frequency lowers slightly until the amplitude builds up to the one volt level.

It can be seen then that the circuit always adjusts the frequency of oscillation so that the gain around the loop is one and the amplitude is one volt rms. If the transfer ratio of the multiplier circuits is changed by a change in the output voltage of A3, the frequency at which the loop gain is one changes and the frequency of oscillation changes accordingly.

Integrators (see schematic on page IX-9): Q4000 through Q4007 with their associated passive components form a multiplier circuit which has an output current equal to the instantaneous input current multiplied by a constant determined by a second input. Q4000 and Q4001 with their collectors tied directly to their bases form a pair of diodes which have their "cathode" (emitter) ends connected together. The average currents though all paths to the "anode" (base) of Q4000 is zero except for the current through R4005. This current flows through Q4000 into R4037 while an equal amount of current flows from ground through Q4001 into R4037. Q4000 and Q4001 have been carefully matched so that they exhibit equal forward voltage drops when equal currents are passed through them.

Since Q4006 and Q4007 have also been matched, the current from Q4016 splits equally when the bases Q4006 and Q4007 are both at ground potential. These currents pass through the common base stage Q4004 and Q4005. The "current reflector" circuit Q4002-4003 converts the current through the collector of Q4004 into an equal and opposite current at the collector of Q4003. This combines and cancels with the current from Q4005 at the output. Offsetting the base of Q4006 from zero unbalances the currents in Q4006 and Q4007 and results in a net output current which is not zero. This current is fed into the capacitor selected by the Frequency Range switch to form an integrator.

Only the average currents to the integrators are zero. Instantaneously, the current through R4002 into the first integrator unbalances the currents through the "diode pair" Q4000-Q4001, which creates a slight difference in the voltage drop across each. This difference is applied to the base of Q4006, causing a net output current into the capacitor as previously described. The characteristics of the diode pair are such that the difference voltage developed by unbalanced currents is exactly the voltage required to unbalance the currents through Q4006 and Q4007 by the same ratio. The ratio of

the currents through Q4006 and Q4007 is independent of the total current through those two from Q4016. Therefore, the output current from the multiplier has a magnitude equal to the fractional unbalance times the current from Q4016.

The other integrator, Q4008 through Q4015, combined with a second capacitor on the Frequency Range switch, operates in an identical manner.

Operation Amplifiers A1 and A2: These amplifiers are identical and only one will be analyzed here. Q4100 and Q4101 form a differential amplifier with gain degeneration by R4103 and R4104 to avoid instability at high frequencies. Current source Q4102 provides the operating current for the first stage. Additional gain is provided by differential amplifier Q4103 and Q4104. Emitter followers Q4108 and Q4109 lower the impedance for the balanced outputs. To assure that the two outputs are exactly equal in amplitude and opposite in polarity, the mean voltage of the two outputs is made equal to zero by the action of differential amplifier Q4106-Q4107. The mean voltage, obtained at the junction of R4116 and R4117, causes a large output voltage swing at the collector of Q4107 if the mean is not zero. This output is buffered by emitter follower Q4105 which regulates the current through differential pair Q4103-Q4104. The current through Q4103-Q4104 directly adjusts the mean voltage at their collectors, and therefore at the two outputs, so that the output mean is held to zero.

Operational Amplifier A3: N-channel, Junction field effect transistor Q4302 is arranged as a differential amplifier with its output further amplified by differential amplifier Q4300-Q4301. The output from the collector of Q4300 is reversed in phase by the "current reflector" Q4304 and then summed with the output current from Q4301. The differential output currents are combined into a single current at twice the amplitude to drive the base of emitter follower Q4303.

The output voltage of A3 determines the oscillation frequency of the Reference Oscillator Board. The voltage which appears at the output of A3 is controlled in various ways. In the INT/VCO mode, the Operational amplifier is arranged as an inverter by connecting feedback resistor R4048 to the summing junction. This is accomplished by externally connecting board connector pin V to pin L (see Chassis Wiring Schematic). In this mode, the Digital Dials are connected as a rheostat between a positive voltage source and the summing junction (pin L). Adjustment of the Digital Dials controls the output voltage of A3. Voltage from the rear panel VCO connector is fed to pin T. This voltage causes plus or minus current through R4061 to flow into the summing junction where it adds to or subtracts from the current from the Digital Dials. In either the EXT. or the EXT. f/2 modes, A3 is arranged as an integrator. External switching connects C4008 as the only feedback path around A3. Plus or minus current from the Auxiliary Reference Board adjusts the integrator's output voltage to obtain the required frequency.

5.6 AUXILIARY REFERENCE BOARD

The main function of the Auxiliary Reference Board is to control the frequency of the Reference Oscillator in either the EXT. or EXT. f/2 modes. In the External mode, the external reference waveform is made rectangular by a

Schmitt Trigger circuit and then sent through a pulse shaper which produces a 20 ns wide positive pulse each time the waveform crosses its mean in a positive direction. A sine wave from the 180° output of the Reference Oscillator receives similar treatment. The two trains of pulses are processed by a Frequency Comparator. The output from the Frequency Comparator is level shifted and sent to the summing junction of A3 on the Reference Oscillator. A3 is arranged as an integrator in the External modes. Since its output voltage determines the Reference Oscillator frequency, signals from the Auxiliary Reference Board into the integrator can cause the Reference Oscillator to lock onto an external reference frequency and track it. After frequency lock has taken place, the Frequency Comparator circuit functions as a phase comparator and the phase of the reference oscillator is thereby also locked to the phase of the external reference. In the EXT. f/2 mode the output of the Schmitt Trigger, which is driven by the 180° sine wave from the Reference Oscillator, is routed through a divide-by-two scaler. The Frequency Comparator must adjust the Reference Oscillator Frequency to twice the frequency of the external reference in order to stabilize.

Schmitt Triggers: The two Schmitt Trigger circuits are identical so that only one, say the one connected to the 180° output of the Reference Oscillator, need be analyzed here. The signal, a sine wave in this case, is coupled through C5017 to the gate of source follower Q5010A. R5038 adjusts the gate bias voltage so that the remainder of the circuit, the Schmitt Trigger itself, fires when the incoming signal crosses through its mean. Diodes CR5007 and CR5008 couple the signal from the source follower to the base of Q5011, which is the input to the Schmitt Trigger. Positive feedback from the collector of Q5011 to the base of Q5012 through R5052 causes the differential transistor pair to rapidly shift the operating current from R5049 through one transistor or the other. The rectangular shaped output drives the inverter/buffer Q5013.

Divide-by-two scaler: Toggled flip-flop U5001 produces rectangular output at half the frequency of its input from Q5013. One of the two NAND gates in this area (each one-fourth of IC package U5004) has an input tied directly to the output of the lower Schmitt Trigger, which is switched at the frequency of the Reference Oscillator. The other is tied to the half-frequency output of the scaler, U5001. The Reference Mode switch, by grounding an input of one or the other of the NAND gates, can inhibit the appearance of an inverted rectangle at the output of that gate. In this way, a waveform at either the same or half the frequency of the Reference Oscillator appears at the "wired-OR" outputs of the two gates.

Pulse Shapers: The output from the Scaler and the output from the Schmitt Trigger operating on the External waveform are each passed through a pulse shaper. The shaper, composed of R5056, C5021, the inverter (one-sixth of IC package U5003) and the NAND gate (one-fourth of U5006) provides a 20 nanosecond wide pulse each time the input to the inverter has a positive transition. When the input is low (near zero volts) the inverter's output is high (approximately 4 volts) and C5021 is charged to the same voltage through R5056. The output of the NAND gate is high since one of its inputs is low. When the input line connected directly to both the inverter and the NAND gate is suddenly switched positive, both inputs to the NAND gate are high. The output of the NAND gate must therefore be low at this moment. After 20 nanosec-

onds, the inverter's output, which was made low when the input went positive, has discharged C5021. Once the voltage on C5021 decays to a sufficiently low level, the output of the NAND gate must return positive. The output of the NAND gate is normally high except for the few nanoseconds following a change of the input level from low to high. The inverter following this NAND gate has an output which is normally low with a train of narrow positive pulses.

Frequency Comparator: The Frequency Comparator is basically two Set-Reset flip-flops. Each flip-flop is actually a pair of NAND gates with cross-coupled feedback. One flip-flop is composed of one-half of U5006 (terminals 8 through 13); the other is one-half of U5002 (terminals 8 through 13). Hereafter these shall be referred to as "first" and "second" flip-flops respectively. The Pulse Shaper outputs set and reset the flip-flops but only after passing through a set of six NAND gates (U5004 terminals 1 through 6 and U5005).

The first flip-flop is always in the 0 state (at U5006 pin 11) unless the two trains of incoming pulses are not at the same frequency, in which case the output is usually in the 1 state. The UNLOCK lamp is on whenever a 1 is present at this output.

The second flip-flop functions in two modes:

(1) When the internal Reference Oscillator is lower in frequency than the external reference, terminal 11 of U5002 is always 1. When the internal oscillator is higher than the external reference, terminal 11 is always 0.

(2) When the internal Reference Oscillator and the external reference are both equal in frequency, the flip-flop functions as a phase detector.

The behavior of the outputs of the two flip-flops depends on how each pulse from the two pulse trains sets or resets each flip-flop. Given that certain states at the outputs of the flip-flops should indicate the most recent history of the two input frequencies, it is then possible to use the output states themselves to control the routing of each incoming pulse in such a way that each pulse sets or resets each flip-flop as required to update the output states properly.

Various outputs of the two flip-flops are fed back to the line of six NAND gates (U5004 terminals 1 through 6 and U5005 terminals 1 through 6 and 8 through 10) to inhibit or enable the passage of pulses through each gate. Each pulse train is fed to three of these gates. A pulse from either shaper will be routed (and inverted) through at least one of the NAND gates to set or reset one or both flip-flops. Since the feedback changes which result are delayed by the RC time constant in each feedback line, only the routing of the subsequent pulse will be changed.

The output of the second flip-flop is further processed before being sent to control the integrator on the Reference Oscillator Board.

OUTPUT CIRCUITRY

The outputs of the second flip-flop must be level shifted to be suitable for

driving the integrator on the Reference Oscillator Board. In the stabilized condition, where the external reference and the 0° output of the internal Reference Oscillator are both frequency and phase locked, the two inputs to the Frequency Comparator, the external reference and the 180° output from the internal reference, are exactly out-of-phase. It has been stated that the second flip-flop operates as a phase detector under these circumstances, and therefore produces a symmetrical square wave. The square wave from the Schmitt Trigger processing the 180° output from the internal Reference Oscillator is available at the input of the lower Pulse Shaper. This square wave, before and after inversion by U5003 13-12, is introduced at the inputs of the NAND gates U5002 1-2-3 and 4-5-6. The outputs of the second flip-flop are also introduced to these gates. The inputs of each NAND gate are alternating in state exactly opposite in phase so that one of the inputs to each gate is always at the 0 level forcing the outputs to remain continuously at 1. Since the output of U5002 1-2-3 is inverted by U5003 11-10, the two lines into the level shifting circuit Q5014 through Q5017 are at levels which turn off both Q5015 and Q5016. No current flows through R5079. The output EØ (phase error) therefore has zero voltage in this case to cause a change in the integrator.

If there is a phase difference between the external and internal references, the square wave at the second flip-flop is unsymmetrical. When the symmetrical square waves from the lower pulse shaper are combined with this and fed to the level shifting circuitry, a series of narrow pulses appear at EØ. The polarity of the pulses is positive if the internal oscillator phase lags the external phase and vice versa. The pulses, after integration, change the frequency of the internal oscillator slightly until phase lock is achieved. The pulses become progressively narrower until, at phase lock, they become non-existent and no further adjustment of the internal oscillator occurs.

If the Frequency Comparator indicates a frequency unlock condition, the pulses at EØ also appear at Ef (frequency error) through FET Q5017. The FET is biased on by a signal from the first flip-flop passed through inverter Q5014. A pulse appearing at Ef produces a current at the integrator much larger than a pulse at EØ since the path it takes through the chassis wiring (see Schematic IX-12) to the integrator is much lower resistance than the path taken by a pulse at EØ. The result is that when frequency error is detected by the Frequency Comparator, the frequency slew rate of the internal oscillator is much greater to correct the difference than it would if only the EØ path were used. The EØ must necessarily be slower for loop stability.

5 V Supply: A simple voltage divider followed by complimentary emitter followers Q5000 and Q5001 provides 5 volts dc to operate the integrated circuits.

5.7 MIXER BOARD

The Mixer board contains much more than just the Mixer (often referred to as a Phase Sensitive Detector or a Demodulator). The last amplifier stage of the Signal Channel is located here as well as the two dc output amplifiers. A Schmitt Trigger develops the proper drive levels for the Mixer itself. The schematic on page IX-13 is an abbreviated diagram of the entire circuit board. The three amplifiers shown as triangular symbols are shown in detail on page IX-14.

Final Ac Amplifier: A signal entering through C3101 is amplified with a non-inverting gain of 11 at the upper output of the amplifier, and an inverting gain of 11 at the lower output. The gain of this operational amplifier is determined by R3119 and R3104 at the normal range of signal frequencies. Since the feedback from this divider is ac coupled, there is much lower gain for any dc offsets which might appear at the front end of this amplifier.

Q3101 and Q3102 form the first differential amplifier with the base of Q3102 serving as the summing junction. Operating current for this stage is provided by current source Q3103. Additional open loop gain is developed by Q3104-Q3105 forming the second differential amplifier. The two collector outputs from the second stage are buffered by the emitter followers Q3108 and Q3109.

To assure that the lower output is exactly equal and opposite from the first, the mean voltage of the two outputs is regulated to zero by the action of the Common Mode Amplifier (CMA). The mean voltage appearing at the junction of R3124 and R3125 is applied to the base of the differential amplifier Q3106-Q3107. If the mean voltage is other than zero, a large voltage swing develops at the differential amplifier's output, the collector of Q3107. This voltage swing adjusts the bias for the current source Q3103, causing a change in the common mode voltage at the front end stage of the ac amplifier itself. This common mode voltage passes through the second stage of the differential amplifier and from there through the output emitter followers completing the regulation loop.

Schmitt Trigger: The REF. INPUT signal into the Schmitt Trigger comes directly from the wiper of the Phase potentiometer when operating in the three PSD positions of the Function switch, or from the Signal Monitor output of the Final Ac Amplifier in the ACVM position. The signal is passed through amplifier Q3001 and Q3002 and from there to amplifier-limiter Q3004-Q3005. Q3003 provides a constant operating current for the amplifier limiter. Q3006 and Q3007 along with cross-coupled feedback through R3016 and R3022 form the Schmitt Trigger itself. Amplifier-limiter Q3008-Q3009 has balanced outputs at the proper levels to drive the FET Mixer.

Mixer: Q3010 through Q3013 are arranged in a full-wave switching circuit, with either Q3010 and Q3013 or Q3011 and Q3012 switched on at any given time according to the state of the Schmitt Trigger. The result is that the Mixer Output at board terminal D is alternately "connected" to each of the two outputs of the Final Ac Amplifier.

The theory of operation is simple. If the Schmitt Trigger is made to switch its state at such times that the Mixer Output is always connected to the output of the Ac Amplifier which is positive, the Mixer output will be positive only. Proper timing is automatic when operating in the ACVM mode since the signal from the AC Amplifier also drives the Schmitt Trigger. In the Phase Sensitive Detector modes, the Schmitt Trigger is slaved to the Internal Reference Oscillator and therefore is switched coherently with the signal. In this case, however, the phase of the reference signal driving the Schmitt Trigger must be adjusted so that the Mixer switches at the desired phase with respect to the signal from the Ac Amplifier.

Output Circuitry: Two low-drift, low-noise, operational amplifiers are the basis of the output circuitry. The gain and frequency response characteristics are determined by the Functions switch and the Time Constant switch.

The gain of the first dc amplifier (DCA-1) is the ratio of the feedback impedance to the input resistor. The resistive feedback to the summing junction is through a resistive network which is equivalent to a simple 30 megohm resistor. The network is composed of the 2.49 kΩ and 10 kΩ divider and the 24 MΩ resistor to the summing junction. The input resistor, selected by the Function switch, has a total value of 100 kΩ, 1 MΩ or 10 MΩ corresponding to gains of 300, 30, or 3. A capacitor, value selected by the Time Constant switch, is connected across the resistive feedback. At high frequencies, the feedback impedance is determined mainly by the reactance of the capacitor so that the gain decreases at a 6 dB/octave rate.

Operation as an integrator is achieved by simply breaking the resistive feedback path. The NORM/HOLD switch can cause the DCA-1 to hold any given output level by breaking both the input and resistive feedback paths, leaving only the capacitor connected.

The second dc amplifier (DCA-2) has permanent input and resistive feedback values which yield a gain of 3.33. The capacitive feedback is connected across DCA-2 only in the 12 dB position of the inner concentric 6 dB/INTEGRATE/12 dB switch. In this position each amplifier exhibits 6 dB/octave for a combined total of 12 dB/octave.

When pressed, the Reset pushbutton discharges both capacitors.

The internal operation of DCA-1 is as follows: The matched monolythic NJFET pair Q3201A-Q3201B, together with its drain load resistors, forms a differential amplifier. Operating current is supplied by Q3202. Additional gain is obtained by the differential amplifier Q3205-3206. The output current of Q3205 is inverted by the current reflector Q3207 and summed with the output current from Q3206 to further increase the current gain of the stage. A low output impedance is obtained by emitter follower Q3208.

DCA-2: The internal operation of DCA-2 is essentially identical to that of DCA-1 except complimentary output emitter followers are employed to provide high current output capability for positive or negative output voltages.

SECTION VI
ALIGNMENT PROCEDURE

6.1 INTRODUCTION

The Model 126 is a reliable instrument, and as such, will give long trouble-free service. However, if it ever becomes evident that the instrument fails to meet specifications because of component aging or as a result of replacement of a faulty component, the following alignment procedure should be carried out. Periodic alignment is generally unnecessary.

Because some of the adjustments interact, the entire alignment should be performed in sequence. Any decision to make only a partial alignment should be reserved to someone having sufficient knowledge of the instrument to determine where interaction is a consideration and where it is not. The location of the various adjustments and test points is indicated in Figure VII-1 on page VII-5.

If any problems are encountered in performing the alignment, the operator is referred to the following section on troubleshooting. If assistance or advice is required, contact the factory or one of P.A.R.'s authorized representatives, a list of whom appears at the end of the manual.

6.2 EQUIPMENT NEEDED

(1) Dc voltmeter, input impedance one megohm or higher, 0.1% accurate.

(2) Oscilloscope, dc to 1 MHz, general purpose.

(3) Ac Voltmeter, accurate to 3% at a 1 V rms level at frequencies from 400 Hz to 200 kHz.

(4) Frequency/Period Counter covering a range of 400 Hz to 200 kHz.

(5) Ac Calibration Standard producing a 100 mV rms sine wave with 1% amplitude accuracy at any frequency from 100 Hz to 1 kHz.

(6) Extender Board for standard 44 pin card-edge connector - Can be obtained from Princeton Applied Research.

(7) Assorted cables as required.

(8) "BNC TEE" connector.

(9) BNC Shorting Cap.

(10) Alignment Screwdriver, non-metallic.

All measurements are taken with respect to chassis ground, unless stated otherwise.

SAFETY CONSIDERATIONS
(READ BEFORE ATTEMPTING ALIGNMENT)

WARNING! POTENTIALLY LETHAL VOLTAGES ARE PRESENT INSIDE THIS APPARATUS. THESE SERVICING INSTRUCTIONS ARE FOR USE BY QUALIFIED PERSONNEL ONLY. TO AVOID ELECTRIC SHOCK, DO NOT PERFORM ANY SERVICING UNLESS QUALIFIED TO DO SO.

Any adjustment, maintenance and repair of the opened apparatus under voltage shall be avoided as far as possible and, if unavoidable, shall be carried out only by a skilled person who is aware of the hazard involved. When the apparatus is connected to a power source, terminals may be live, and the opening of covers or removal of parts is likely to expose live parts. The apparatus shall be disconnected from all voltage sources before it is opened for any adjustment, replacement, maintenance, or repair. Capacitors inside the apparatus may still be charged even if the apparatus has been disconnected from all voltage sources. Service personnel are thus advised to wait several minutes before assuming that all capacitors are discharged.

Make sure that only fuses with the required rated current and of the specified type are used for replacement. The use of makeshift fuses and the short-circuiting of fuse holders are prohibited.

6.3 PRELIMINARY STEPS

(1) Remove the top and bottom covers.

(2) Set the front panel controls as follows.

Sensitivity	500 mV
L.F. Rolloff	1 kHz
H.F. Rolloff	1 kHz
Reference Mode	INT/VCO
Reference Frequency Dials	Red knob, NORMAL; Digits, 4.0
Reference Frequency Range	X100
Reference Level	1 V (fully cw)
Phase Potentiometer	0° (fully ccw)
Phase switch	0°
Hold/Normal switch	NORM.
Time Constant switch	Red knob, 6 dB; Black knob, 300 ms.
Function switch	X1
Zero Offset Potentiometer	0 (fully ccw)
10X Full Scale switch	Off (center position)

This procedure is based on the use of a type 117 preamplifier or either a type 116 or 119 preamplifier operated in the DIRECT mode. A Model 118 preamplifier can be substituted if its increased sensitivity is taken into account by decreasing all input levels prescribed in this procedure by a factor of ten.

See Figure VII-1 for board locations and adjustment locations.

6.4 POWER SUPPLY BOARD

(1) Place the Power Supply Board on the Extender Board.

(2) Turn Power switch ON.

(3) Connect a digital voltmeter (DVM) to the yellow test point. Adjust R6028 (5 kΩ pot) for -24.0 V ±0.1 V.

(4) Connect the DVM to the red test point. Adjust R6010 (2 kΩ pot) for +24.0 V ±0.1 V.

(5) Turn the power off. Remove the Extender Board and plug the Power Supply Board into its normal position in the chassis connector.

6.5 REFERENCE OSCILLATOR BOARD

(1) Place the Reference Oscillator Board on the Extender Board.

(2) Turn the Power switch ON.

(3) Connect a DVM to the white test point and check for 0 ±0.5 V.

(4) E ZERO 3 Adjustment

(a) Connect an oscilloscope to the gray test point. Set the oscilloscope controls for dc coupling and 5 V/cm sensitivity.

(b) Connect a clip lead from pin L to pin M.

(c) Attempt to set the E ZERO 3 potentiometer for 0 volt output. The correct setting is the critical point where very slight shifting of the adjustment one way or the other will cause the output to swing several volts positive or negative.

This behavior indicates very high open-loop gain desired in the operational amplifier A3. This gain greatly magnifies the slightest offset in the adjustment of the potentiometer whenever the inputs are shorted.

(d) Remove the clip lead. Disconnect the oscilloscope.

(5) Connect the DVM to the gray test point and check for -3.8 ±0.3 V.

(6) I ZERO 1 Adjustment

(a) Connect a clip lead from test point B1 to chassis ground.

(b) Connect another clip lead from test point E1 to chassis ground.

(c) Monitor the green test point with the oscilloscope.

(d) Adjust I ZERO 1 for a condition where the output is drifting very slowly about 0 V.

Eventually, the output will drift far from 0 V but this should not be interpreted as an indication of either correct or incorrect adjustment.

(e) Remove only the clip lead from test point E1 to ground.

(7) E ZERO 1 Adjustment

(a) Adjust E ZERO 1 potentiometer for 0 V. Drifting of the voltage is normal even after adjustment.

(b) Remove the remaining clip lead from test point B1 to ground.

(8) I ZERO 2 Adjustment

(a) Attach a clip lead from test point B2 to chassis ground.

(b) Connect another clip lead from test point E2 to ground.

(c) Monitor the violet test point with the oscilloscope.

(d) Adjust I ZERO 2 potentiometer for a condition where the output is drifting very slowly about 0 V.

Eventually, the output will drift far from 0 V but this should not be interpreted as an indication of either correct or incorrect adjustment.

(e) Remove the clip lead from test point E2 to ground.

(9) E ZERO 2 Adjust

(a) Adjust E ZERO 2 potentiometer for 0 V. Drifting of the voltage is normal even after adjustment.

(b) Remove the remaining clip lead from test point B2 to ground.

(10) Using the oscilloscope, check for a 2.8 ±0.3 V pk-pk sine wave at the violet test point. Similarly, check for a sine wave at the white, green, and blue test points.

(11) Reference Output Check

(a) Connect the oscilloscope to the front panel Reference OUT connector and check for a 2.8 ±0.3 V pk-pk sine wave. If the Model 126 is equipped with the Reference Power Amplifier Option, the voltage should be a factor of ten greater.

(b) Set the Reference Level potentiometer to 10 mV rms. The oscilloscope should indicate 20 to 40 mV pk-pk. (With the Reference Power Amplifier Option, the indication should be 200 to 400 mV pk-pk.)

(c) Return the Level control to its full clockwise position.

(12) Turn the Power switch OFF. Remove the Extender Board and return the Reference Oscillator Board to its normal position in the chassis.

6.6 AUXILIARY REFERENCE BOARD

(1) Place the Auxiliary Reference Board on the Extender Board.

(2) Turn Power switch ON.

(3) Connect the DVM to the "+" end of C5005, a 15 µF 6 V electrolytic capacitor near the top central area of the board. The voltage should be 5 ±0.25 V.

(4) Connect the DVM to the + end of C5004, a 35 µF 25 V electrolytic capacitor at the top edge of the board. The voltage should be greater than +8 V. Remove DVM.

This measurement is a check that the current load on the 5 V dc supply is normal.

(5) INT. ZERO (Square Wave Symmetry) Adjustment

(a) Connect the oscilloscope to the blue test point and check for a 4.5-to-5.0 V pk-pk square wave.

(b) Set the oscilloscope sweep time base to 0.2 ms/cm.

(c) Adjust the oscilloscope controls so that it triggers on the + leading edge of the square wave cycle.

(d) Note the exact position of the falling edge of the waveform on the oscilloscope; the oscilloscope's horizontal magnifier may be used for better resolution.

(e) Change the oscilloscope triggering controls so that the sweep starts at the negative falling edge. The positive leading edge of the waveform should now appear near the position noted in the previous step.

(f) Adjust the INT. ZERO potentiometer so that there is minimum difference in the two positions described in steps c, d, and e.

(6) EXT. ZERO (Square Wave Symmetry) Adjustment

(a) Connect the oscilloscope to the green test point.

(b) Connect a BNC cable from the Reference OUT connector to the Reference IN connector.

(c) Check for a 4.5-to-5.0 V pk-pk square wave.

(d) Slowly turn the Reference Level control counter-clockwise. If necessary, adjust the EXT. ZERO potentiometer for best symmetry.

NOTE: A point will be reached when the Level control will be too low and the waveform will remain locked to either + or ground level.

(e) Remove the cable.

(7) Reference Lock Check

(a) Connect the oscilloscope to the Reference OUT connector.

(b) Using a signal generator, feed a 400 Hz, 1 V rms sine wave to both the Reference IN connector and the oscilloscope's external trigger input; a BNC TEE connector will probably be required.

(c) Set the oscilloscope sweep time base to 0.5 ms/cm.

(d) Place the Reference Mode toggle switch to EXT. The oscilloscope pattern should lock within a second or two. Be sure the oscilloscope is adjusted for proper external triggering. The Reference Unlock lamp should be extinguished.

(e) Set the Reference Range switch to X1K. The Unlock lamp should glow for about a second after which time the sine wave should appear locked on the oscilloscope.

(f) Set the Reference Range switch to X100. The lamp should glow for about 5 seconds. After the lamp is extinguished, the oscilloscope pattern should again be stationary. Two cycles of a sine wave should be displayed on the screen.

(g) Place the Reference Mode switch to f/2.

(h) When the Unlock lamp turns off, four stationary cycles should appear.

(i) Place the Reference Mode switch to INT/VCO. Turn the Power switch OFF. Return the Auxiliary Reference Board to its standard place in the chassis.

6.7 MIXER BOARD

(1) Schmitt Trigger Waveform Check

(a) Connect the oscilloscope to the blue test point. Trigger the oscilloscope externally from the Reference OUT connector.

(b) Check for a square wave of approximately 20 V pk-pk amplitude.

(c) Disconnect the oscilloscope.

(2) DCA-2 ZERO Adjustment

(a) Attach a clip lead from TP3301 to TP3303 (ground). Attach a second clip lead from TP3302 to TP3303.

(b) Adjust DCA-2 ZERO potentiometer for a panel meter reading as near to zero as possible.

(c) Remove the two clip leads.

(3) DCA-2 Differential Input Current Zero

THIS STEP SHOULD ONLY BE PERFORMED IF THE FET Q3201 IS REPLACED.

(a) Connect a clip lead from the junction of the 24 megohm resistor R64 and the 10 kilohm resistor R60 located on the rear two decks of the Time Constant switch to TP3303.

(b) Connect a clip lead from pin 11 of the card-edge connector to TP3303.

(c) If necessary, replace R3301 with a value which results in a meter reading within ±10% of zero. The value should fall in the range of 10 kilohms to 6.8 megohms.

A few moments settling time may be required to obtain a reading.

(d) Remove the clip leads.

(4) Turn the Power switch OFF. Place the Mixer Board in its normal position in the chassis. Restore power to the instrument.

(5) DIFFERENTIAL ZERO Adjustment

(a) Connect the oscilloscope to the Function OUT connector at the front panel.

(b) Set the Time Constant switch to MIN.

(c) Adjust the DIFF. ZERO potentiometer for minimum ripple on the oscillopscope.

(d) Return the Time Constant switch to 300 ms. Disconnect the oscilloscope.

(6) DCA-1 ZERO Adjustment

(a) Set the Function switch to X100.

(b) Connect the DVM to the Function OUT BNC connector.

(c) Adjust the DCA-1 potentiometer for zero on the DVM.

(7) Symmetry Adjustment

(a) Set the controls as follows:

L.F. Rolloff ---------- MIN.
H.F. Rolloff ---------- MAX.
Function switch ---------- ACVM

(b) Install a Preamplifier at this time if one has not already been installed. (Refer to the paragraph in 6.3.) Set the toggle switches to DIRECT (if applicable) and "A".

(c) Connect a signal generator to the "A" input of the Preamplifier. Set the signal generator frequency to 800 Hz and adjust the amplitude for a 1/2 scale meter reading.

(d) Set the Function switch to X100.

(e) Adjust the signal generator's frequency slightly to obtain a "beat" oscillatory motion on the meter of about one cycle per second.

(f) Adjust the SYM.ADJ. potentiometer for a minimum peak-to-peak amplitude.

(g) Set the Phase switch to 90°. Allow several seconds for the beat to stabilize. Note the beat amplitude. Now adjust the SYM.ADJ. potentiometer to reduce the amplitude by 1/2.

(h) Return the Phase switch to 0°. Check to see that the beat amplitude is the same on both the 0° and 90° settings.

(8) 200 kHz Zero Adjustment

(a) Remove the signal input cable from the Preamplifier. Place a shorting cap on the "A" input.

(b) Set the Reference Frequency controls as follows:

Reference Frequency Dials ------- Red knob, ADD 10;
Digits, 10.0
Reference Frequency Range ------- X10K

(c) Using a non-metallic alignment screwdriver, adjust C3011, the small ceramic trimmer, for zero meter reading. CAUTION: The Mixer Board and its components have been coated with a silicon wax compound to prevent surface electrical leakage. If the rotor of the trimmer does not turn freely, do not force it. It may be necessary to warm the trimmer slightly to soften the wax before adjustment in order to avoid damage.

(d) Return the controls to their previous position as shown:

Reference Frequency Dials ------- Red, NORMAL;
Digits, 4.0
Reference Frequency Range ------- X100
Function switch ---------- ACVM

6.8 SENSITIVITY CALIBRATION

(1) Meter Calibration

(a) Connect the DVM to the Function OUT connector. The reading should be within a few millivolts of zero.

(b) With the Model 126 in a normal operating position, adjust the meter mechanical zero for zero meter deflection.

(c) Set the small 10X Full Scale toggle switch to -. Then adjust the Zero Offset potentiometer for a reading of 10.0 V on the DVM.

(d) Place the instrument somewhat forward on the bench so that the small printed circuit board mounted on the Function switch is accessible from the bottom of the instrument.

(e) Adjust the METER CAL potentiometer for exactly full scale meter deflection. This potentiometer is the one located nearest the center of the front panel.

(f) Remove the shorting BNC cap from the "A" input on the preamplifier. The DVM should remain connected.

(2) Sensitivity Adjustment

(a) Set the front panel controls as follows:

Sensitivity ---------- 100 mV
10X Full Scale switch ---------- Off (center position)

(b) Connect a sine wave voltage standard to the "A" input of the preamplifier. Set the standard to produce a level of 100 mV rms at any frequency in the range of 100 Hz to 1 kHz.

(c) Adjust the SENS ADJ potentiometer for exactly 10.00 volts on the DVM. This control is located on the printed circuit board mounted on the Sensitivity, L.F., and H.F. switches.

(d) Disconnect the voltage standard.

(3) Output Gain Adjustment

(a) Set the front panel controls as follows:

Sensitivity ---------- 1 mV
Reference Level ---------- 0 (fully ccw)
Phase potentiometer ---------- 90° (9 turns from fully ccw)
Phase switch ---------- 270°

(b) Connect a cable between the "A" input of the preamplifier and the Reference OUT connector.

(c) Advance the Reference Level control to obtain a reading of 90% of full scale; the DVM should now read about 9 V.

(d) Set the Function switch to X1.

(e) Adjust the Phase potentiometer setting slightly for maximum positive DVM reading. The voltage should be approximately 9 V. Note the exact voltage.

(f) Set the Sensitivity switch to 100 mV and the Function switch to X100.

(g) Adjust the CAL 1 potentiometer so that the DVM reads the same as it did in step 'e'. This control is located on the Function switch printed circuit board.

(h) Disconnect the cable and the DVM.

6.9 FREQUENCY CALIBRATION (Reference Oscillator Board)

(1) AC BAL 1 and AC BAL 2 Adjustments

(a) Connect an ac voltmeter to the white test point (90°) on the Reference Oscillator Board and check for an amplitude of approximately 1 V rms.

(b) Connect a frequency counter to the green test point (270°). It should indicate a frequency of about 400 Hz. Be sure the Reference Frequency controls are still set for 4.0, X100.

(c) Note the reading on the ac voltmeter at the white test point, and then connect the meter to the blue test point (0°). Adjust the AC BAL 1 potentiometer for the same amplitude noted at the white test point.

(d) Check for equal amplitudes at the white and blue test points. If necessary, repeat step 'c'.

(e) The amplitude at this time should be 1.0 ±0.1 V rms.

(f) Note the reading on the frequency counter. Calculate the difference between the counter reading and 400 Hz. Adjust the AC BAL 1 potentiometer to reduce the difference by exactly 1/2.

(g) Adjust AC BAL 2 potentiometer to obtain exactly 400 Hz reading on the frequency counter.

(h) Recheck the amplitudes at the white and blue test points. They should still be equal and 1.0 ±0.1 V rms.

(2) High Frequency Amplitude Adjust

(a) Set the Reference Frequency controls to obtain 20 kHz--NORMAL, 2.0, and X10K.

(b) Note the exact frequency on the counter; it should be approximately 20 kHz.

(c) Set the Reference Frequency controls for 200 kHz--ADD 10, 10.0, and X10K.

(d) Connect an ac voltmeter to the blue test point.

(e) Adjust C4010 for a reading of 1.00 ±0.01 V rms. C4010 is the ceramic trimmer capacitor nearest the center of the Reference Oscillator Board.

(3) 200 kHz Frequency Linearity Adjustment

(a) Adjust C4002 for the frequency which is 10 times the frequency of that noted in step 2(b) above.

(b) Recheck the frequency at the 20 kHz setting and repeat the previous step if necessary.

(4) Reference Capacitor Tailoring

The capacitors which affect frequency accuracy on the four lower bands are carefully selected and matched at the factory and no tailoring is required to meet the published specification for the frequency accuracy on these bands. The X10K band, however, is affected by stray capacitance in the chassis wiring and tailoring is therefore required.

(a) Set the Reference Frequency controls to 20 kHz.

(b) Check the frequency counter reading; if it indicates a frequency in the range of 19.6 to 20.4 kHz no tailoring is necessary and the remaining steps should be ignored.

(c) If the reading is out of the range given in the preceding step, the two small mica capacitors mounted on the Reference Oscillator card-edge connector should be replaced by two similar capacitors of the value required to achieve calibration. Select a new pair of equal-valued capcitors which results in a frequency counter reading of 20 kHz. One capacitor should be installed from pin 12 to pin 13 on the connector, the other from pin 19 to pin 20.

NOTE: Each 5 pF increase in the value of each capacitor will reduce the frequency by 0.1 kHz.

SECTION VII
TROUBLESHOOTING

7.1 INTRODUCTION (SEE SAFETY NOTICE ON PAGE VI-1A BEFORE PROCEEDING)

In spite of the use of highly reliable components throughout the Model 126 and the various plug-in Preamplifiers, there might come a time when component deterioration or even failure could occur, causing the instrument to no longer meet specifications or become inoperative. Generally, a partial or complete realignment (Section VI) will restore proper operation. In the case of component failure, realignment would be neither sufficient nor possible. This section is included as a guide to locate the printed circuit board or other subassembly where the faulty circuit lies, but not necessarily to locate the faulty component itself.

Before any actual repair is attempted, it is strongly recommended that P.A.R. be contacted for advice on the relative merits of field repair vs. returning the instrument to the factory. If the instrument is still in Warranty (Section VIII), it is especially important that the factory be contacted prior to attempting a field repair, as failure to do so could invalidate the Warranty.

It is important that the steps in this section be performed in sequence. Otherwise, the results obtained might easily be misinterpreted, and a normally functioning circuit identified as being faulty.

7.2 SOLDERING TECHNIQUES FOR THE MODEL 126 PRINTED CIRCUIT BOARDS

7.2A REMOVING COMPONENTS

In removing a component from a circuit board, one must take special care not to damage the printed circuitry or the pads. As a first step towards achieving this objective, it is necessary to cut off the component leads above the board. This must be done because of the method used to secure components to the board. When the components are installed at the factory, a machine is used which cuts off the leads below the board, while at the same time exerting pressure against the 'stub', expanding it tightly against the pad, and increasing the diameter of the stub to where there is no way it can be drawn up through the hole from above. This operation gives a joint which is mechanically and electrically secure, but at the same time results in the necessity for cutting off a component's leads to remove the component from the board.

Once the leads have been removed, either of two methods can be used to clean up the pad. Both methods are described in the following procedure.

(1) Cut off the leads above the board.

(2) If necessary, bend the leads straight so that there will be no problem getting them down through the holes when heat is applied.

(3) Heat the pad, using a good soldering iron of moderate power (WALL type 14HDG40120 with a type W14KS tip). Go easy. Too much heat will lift the foil from the board.

(4) As the solder begins to flow, poke or push the lead from above to get it started. Once it moves at all, grasp it from below with long nose pliers and pull it on through.

(5) Clean the pad area, using either the vacuum-bulb or wicking process as follows.

(a) Bulb

Apply heat to the pad until the solder begins to flow. Then use a vacuum-bulb operated solder remover such as the UNGAR type SOLDER-OFF #7805 to remove the solder from the pad and hole. Be careful to apply heat no longer than necessary.

(b) Wicking

In wicking, a length of stranded wire or shielding braid is used to draw up the molten solder from the pad. In addition to a soldering iron, one needs a supply of stranded wire (or braid) and some rosin base soldering flux (ALPHA 346-35 or equivalent). To remove the solder, first dip a few inches of the stranded wire into the flux. Then place the wire on the pad, allowing some of the flux to flow over the pad. (NOTE: Under no circumstances use an acid base flux.) Next place the soldering iron on top of the wire. Within a few seconds, most of the solder in the area will melt and flow quickly up the wick, leaving the pad free of solder. The soldering iron can then be removed and the wick quickly lifted before it freezes to the pad. Cut off the 'filled' end of the wick (generally half an inch should be removed) before proceeding to the next pad.

7.2B INSTALLING COMPONENTS

In returning the component or its replacement to the board, make sure the leads are bent on the proper centers and that they don't angle in or out. If they do not pass freely through the centers of the holes, they may catch the edge of the print and lift it. Bend and cut the leads after inserting the component; then solder the leads with a hot iron (no larger than 40 watts) and a good grade of rosin core 60/40 solder. Be sure to apply heat no longer than necessary to achieve a good joint (usually a few seconds).

7.3 EQUIPMENT NEEDED

(1) Oscilloscope, general purpose.

(2) Dc Voltmeter, 0.1% accurate.

(3) Signal Generator, capable of producing sine wave output at various levels from 1 mV pk-pk to 1 V pk-pk at 1 kHz.

7.4 PRELIMINARY STEPS

(1) Remove the top and bottom covers. The top is held in place by two

screws located just under the rear fold. The two screws through the rear rubber feet hold the bottom cover in place.

(2) Set up the front panel controls as follows:

Meter	Check mechanical zero. Adjust if necessary.
Preamplifier	Select A input and DIRECT (if applicable).
Sensitivity switch	50 mV
L.F. Rolloff	MIN.
H.F. Rolloff	MAX.
Frequency Mode switch	INT/VCO
Reference Frequency Dials	Red knob, NORMAL; Digits, 4.00
Reference Frequency Range	X100
Phase Potentiometer	0° (fully ccw)
Phase Switch	0°
Hold/Normal switch	NORM.
Time Constant switch	Red knob, 6 dB Black knob, 300 ms
Function switch	ACVM
Zero Offset	0 (fully ccw)
10X Full Scale switch	Off (center position)
Power toggle switch	ON

7.5 POWER SUPPLY

(1) Check unregulated voltages at J6, the 44 pin connector located nearest to the power transformer. (Refer to the diagrams in Figure VII-1 and to the Chassis Wiring Schematic.) BE SURE THAT THE 115/230 SWITCH MOUNTED NEAR THE POWER TRANSFORMER IS IN THE CORRECT POSITION.

(a) +31 ±4 V at pin 18; -31 ±4 V at pin 16. If the voltages are within tolerance, proceed to (2).

(b) Check F1, the fuse in the rear panel mounted fuseholder. Replace if necessary. If the fuse blows again, the power transformer, rectifier diodes (CR3, 4, 5, and 6), filter capacitors (C27, 28), and wiring in this area should all be inspected.

(2) Check regulated voltages at the test points located at the top edge of the Power Supply Board.

(a) -24 ±0.2 V at the red test point; +24 ±0.2 V at the yellow test point. If the voltages are within tolerance, proceed to 7.6 Reference Oscillator.

(b) If not, check fuses F6000 and F6001. Replace if necessary. If the fuse blows again, remove the Preamplifier, disconnect the red and yellow wires to the front-panel mounted Signal Amplifier Board, and remove all plug-in printed circuit boards except the Power Supply Board. Replace the fuse again; if it still blows,

the problem is in the Chassis Wiring (including the power pass transistors Q1 and Q2) or in the Power Supply Board itself. If the fuse holds, reinstall the preamplifier and the printed circuit boards one at a time to determine which might be overloading the fuses.

7.6 REFERENCE OSCILLATOR

(1) Check for -3.8 ±0.2 V at the gray test point on the Reference Oscillator Board. Presence of this voltage indicates normal functioning of the front panel digital controls and operational amplifier A3 located on this board.

(2) Check for a 2.8 V pk-pk 400 Hz sine wave at the blue (0°) test point. Similarly, check for the presence of a 2.8 V pk-pk sine wave at the violet (180°), white (90°), and green (270°) test points.

(3) Connect the oscilloscope to the Reference Channel Output connector at the front panel and check for a 2.8 V pk-pk sine wave with the Reference Level control set to 1 V rms (28 V pk-pk if the Model 126 has the Power Amplifier Option installed).

7.7 AUXILIARY REFERENCE

(1) Connect a 1 V pk-pk sine wave from the test generator to the external IN connector in the Reference Channel section of the front panel.

(2) Set the nearby toggle switch to EXT. The REF. UNLOCK lamp should glow for approximately four seconds and then extinguish.

(3) With the Reference Level control at 1 V rms, a 2.8 V pk-pk sine wave at 1 kHz should appear at the Reference Channel OUT connector.

(4) Set the toggle switch to EXT. f/2. After an approximately seven-second period of lamp glow, the output sine wave should have a frequency of 2 kHz. Return the toggle switch to INT/VCO.

If the measurements taken in these first four steps were as indicated, go directly to 7.8. If not, continue with the following steps

5 V Supply:

(5) Check for +11 ±2 V at the + end of C5004, the 35 µF 25 V electrolytic capacitor near the top of the Auxiliary Reference Board. Also check for +5 ±0.5 V at the + end of C5005, the 15 µF 6 V capacitor at the top center of the board.

If the voltages are normal, the 5 volt supply is operating properly and supplying an expected amount of current.

Schmitt Triggers:

(6) Check for a 400 Hz square wave at the blue test point. The upper and

lower voltages of the wave should be +4.5 ±1 V and +0.3 ±0.3 V respectively. If as described, the Internal Schmitt Trigger driven from the 180° output of the Reference Oscillator is operating normally.

(7) Similarly check for a 1 kHz square wave at the green test point to ascertain if the Schmitt Trigger driven by the external reference is normal.

Frequency Comparator:

A thorough check out procedure for this circuit for all possible combinations of input frequencies is beyond the scope of this manual. Nevertheless, failure to pass steps (8) and (9) is a clear indication of malfunction. If these tests are passed, no clear assumptions on the normality of this circuit can be made.

(8) Check for +4 ±1 V at pin 11 of U5006.

IC packages U5001 through U5006 are labeled as "1" through "6" with the labels appearing as small etched-foil digits on the opposite side of the printed circuit board from the components. Pin 1 of each of the 14 pin packages is similarly marked. Counting of pins is clockwise from this side.

(9) Using the oscilloscope, check at the gray test point (TP5002) for a 400 Hz square wave with its lower level at 0 V. There are actually two upper levels, both between +3 and +4 V.

If steps (5) through (9) do not reveal a faulty circuit, and yet the operation still is not proper, the chassis wiring (including the switches) associated with this board should be inspected.

7.8 PREAMPLIFIER

This Preamplifier check is based on the Model 117. (Refer to the Preamplifier Comparison Chart on page II-2.) When following this procedure while using a Model 116 or Model 119 Preamplifier, set the front panel switch to DIRECT. While using a Model 118, reduce all prescribed input levels by a factor of 10. In the case of a Model 184, refer to the Model 184 instruction manual for operational checkout.

(1) Set the Input Selector switch to A.

(2) Connect a 100 mV pk-pk sine wave from a signal generator to the A input.

(3) Connect the oscilloscope to the green test point of the front panel mounted Signal Amplifier Board. (This point is directly wired to the Preamplifier's output.)

(4) Check for a 5 V pk-pk sine wave on the oscilloscope. Change the Sensitivity switch setting to 100 mV. If the oscilloscope now indicates 500 mV pk-pk, the Preamplifier can be assumed to be functioning normally. Return the Sensitivity switch to 50 mV.

7.9 SIGNAL AMPLIFIER BOARD

(1) Connect the oscilloscope to the blue test point and check for a 1.1 V pk-pk sine wave.

Sensitivity Setting	Input Voltage	Voltage Which Should Appear at Terminal 1
100 µV	1 mV pk-pk	1 V pk-pk
200 µV	1 mV pk-pk	500 mV pk-pk
500 µV	1 mV pk-pk	200 mV pk-pk
1 mV	10 mV pk-pk	1 V pk-pk
2 mV	10 mV pk-pk	500 mV pk-pk
5 mV	10 mV pk-pk	200 mV pk-pk
10 mV	100 mV pk-pk	1 V pk-pk
20 mV	100 mV pk-pk	500 mV pk-pk
50 mV	100 mV pk-pk	200 mV pk-pk
100 mV	1 V pk-pk	1 V pk-pk
200 mV	1 V pk-pk	500 mV pk-pk
500 mV	1 V pk-pk	200 mV pk-pk

Table VII-1. GAIN VS. SENSITIVITY SWITCH SETTINGS

(2) Set the L.F. and H.F. Rolloff switches both to 1 kHz. The voltage at the blue test point should drop to 0.55 ±0.1 V pk-pk. Return the switches to MIN. and MAX. positions respectively.

(3) Lower the test signal amplitude to 1 mV pk-pk. Set the Sensitivity switch to 100 µV and check for 1 V pk-pk at terminal 1. Of the row of terminals riveted to the bottom edge of the printed circuit board, terminal 1 is at the end nearest to the Sensitivity switch.

(4) Similarly, check the gain versus Sensitivity switch settings according to Table VII-1.

7.10 MIXER BOARD

Ac Amplifier:

(1) Connect the oscilloscope to the Reference Channel OUT connector and adjust the Reference Level control for 50 mV rms (140 mV pk-pk). Remove the oscilloscope and connect the 50 mV rms sine wave to the Preamplifier's A input.

(2) Check for a 3.1 V pk-pk sine wave at the green test point on the Mixer Board.

Schmitt Trigger:

(3) Connect the oscilloscope to pin 1 of J3, the Mixer Board card-edge

connector. A 3.1 V pk-pk sine wave at 400 Hz should appear.

This sine wave is the output of the Ac Amplifier measured in step (2) and routed to this point by the Function switch in the ACVM position only.

(4) Connect the oscilloscope to the blue test point. A square wave should be present with the upper level at +6 V and the lower level at -12 V.

Mixer:

(5) Connect the oscilloscope to the gray test point. A "full-wave rectified" waveform with peak voltages at approximately 0 and +1.6 V should appear.

Dc Amplifier-1

(6) Connect a dc voltmeter to pin 11 of J3, the Mixer Board card edge connector, and check for -3 ±0.5 V.

Dc Amplifier-2

(7) Connect the dc voltmeter to the front panel output connector located near the Function switch and check for +10 ±1 V.

SECTION VIII
WARRANTY

EG&G PRINCETON APPLIED RESEARCH warrants each instrument of its manufacture to be free from defects in material and workmanship. Obligations under this Warranty shall be limited to replacing, repairing or giving credit for the purchase price, at our option, of any instrument returned, freight prepaid, to our factory within ONE year of delivery to the original purchaser, provided prior authorization for such return has been given by our authorized representative.

This Warranty shall not apply to any instrument which our inspection shall disclose to our satisfaction, has become defective or unworkable due to abuse, mishandling, misuse, accident, alteration, negligence, improper istallation or other causes beyond our control. Instruments manufactured by others, and included in or supplied with our equipment, are not covered by this Warranty but carry the original manufacturer's warranty which is extended to our customers and may be more restrictive. Certain subassemblies, accessories or components may be specifically excluded from this Warranty, in which case such exclusions are listed in the Instruction Manual supplied with each instrument.

We reserve the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

THERE ARE NO WARRANTIES WHICH EXTEND BEYOND THE DESCRIPTION HEREIN. THIS WARRANTY IS IN LIEU OF, AND EXCLUDES ANY AND ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESSED, IMPLIED OR STATUTORY, INCLUDING MERCHANTABILITY AND FITNESS, AS WELL AS ANY AND ALL OTHER OBLIGATIONS OR LIABILITIES OF EG&G PRINCETON APPLIED RESEARCH, INCLUDING, BUT NOT LIMITED TO, SPECIAL OR CONSEQUENTIAL DAMAGES. NO PERSON, FIRM OR CORPORATION IS AUTHORIZED TO ASSUME FOR EG&G PRINCETON APPLIED RESEARCH ANY ADDITIONAL OBLIGATION OR LIABILITY NOT EXPRESSLY PROVIDED FOR HEREIN EXCEPT IN WRITING DULY EXECUTED BY AN OFFICER OF EG&G PRINCETON APPLIED RESEARCH.

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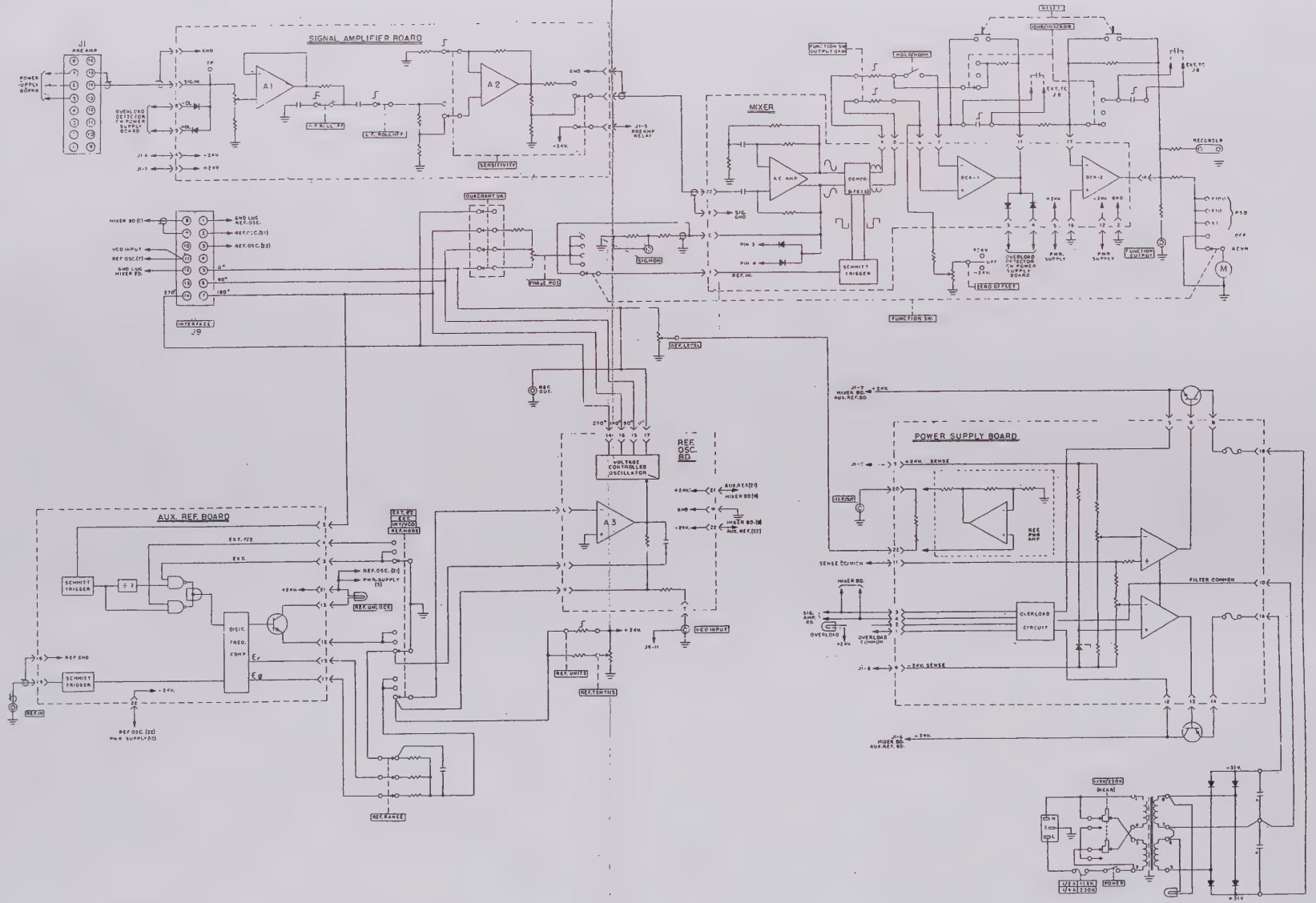

BLOCK DIAGRAM

MODEL 126

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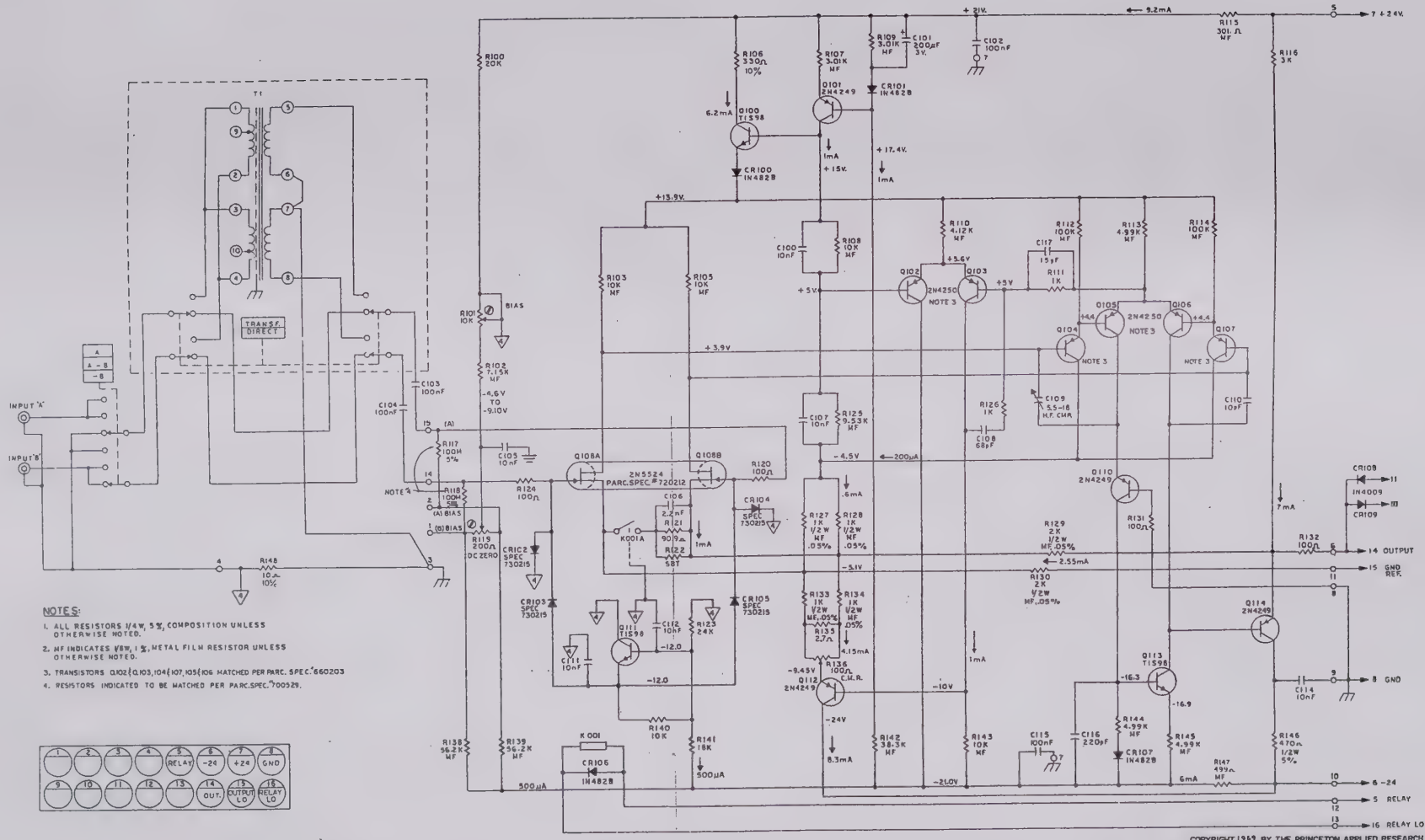

NOTES:

1. ALL RESISTORS 1/4 W, 5%, COMPOSITION UNLESS OTHERWISE NOTED.
2. MF INDICATES 1/8W, 1%, METAL FILM RESISTOR UNLESS OTHERWISE NOTED.
3. TRANSISTORS Q102 & Q103, 104 & 107, 105 & 106 MATCHED PER PARC. SPEC. 660203
4. RESISTORS INDICATED TO BE MATCHED PER PARC.SPEC. 700529.

DIFFERENTIAL PREAMPLIFIER
SUB ASSEMBLY 1160-2000-00s

MODEL 116

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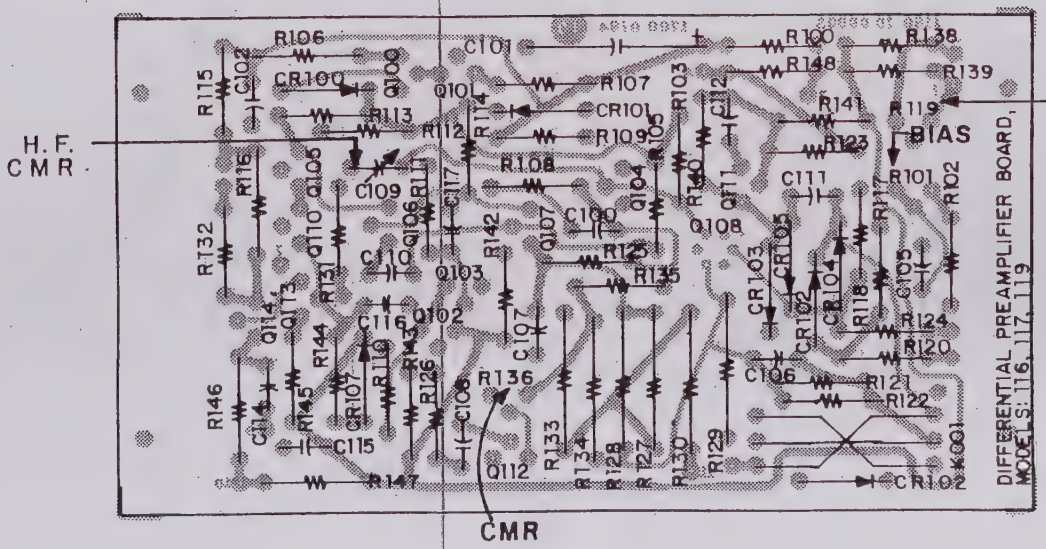
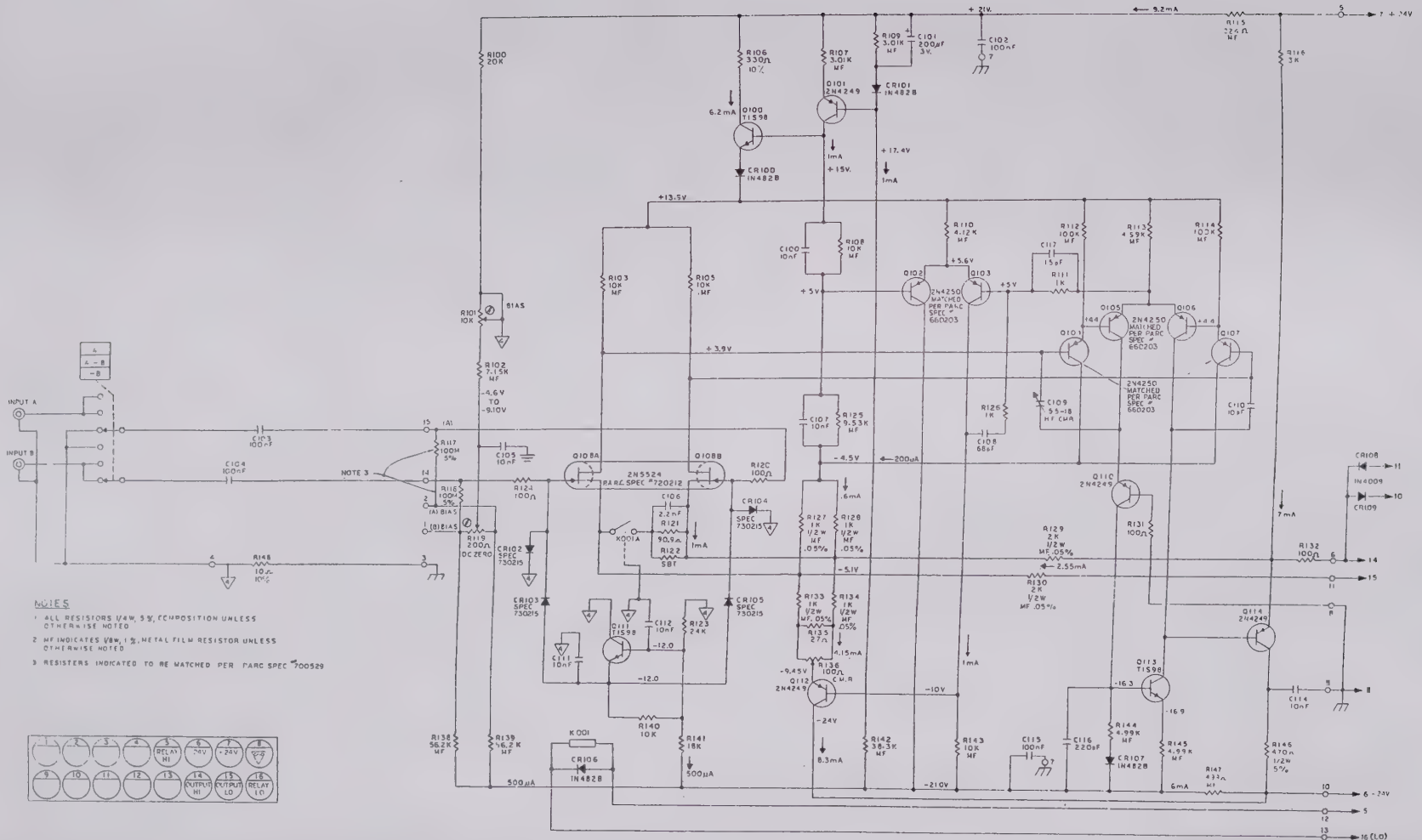
4852 D SD F



SYMBOLIZATION MASTER

DIFFERENTIAL PREAMPLIFIER BOARD

MODELS: 116, 117, 119



DIFFERENTIAL PREAMPLIFIER
SUB ASSEMBLY 1160-2000-00S

MODEL 117

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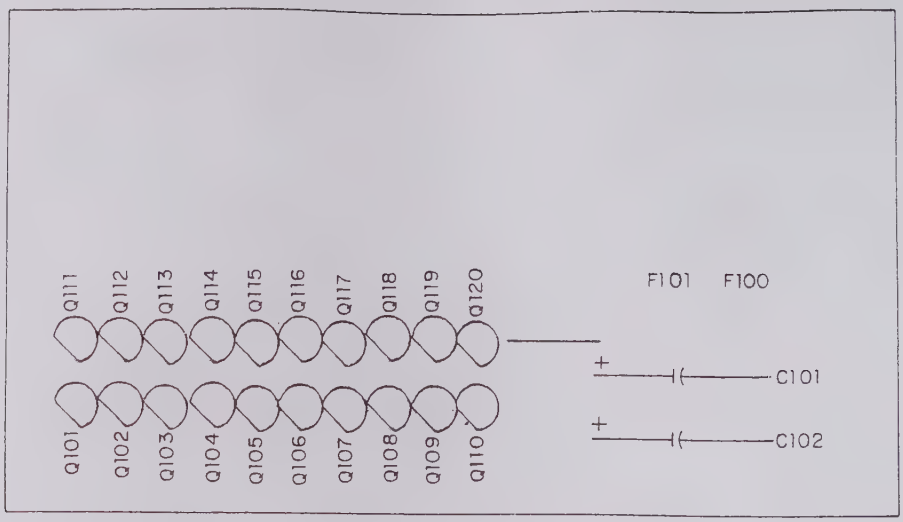
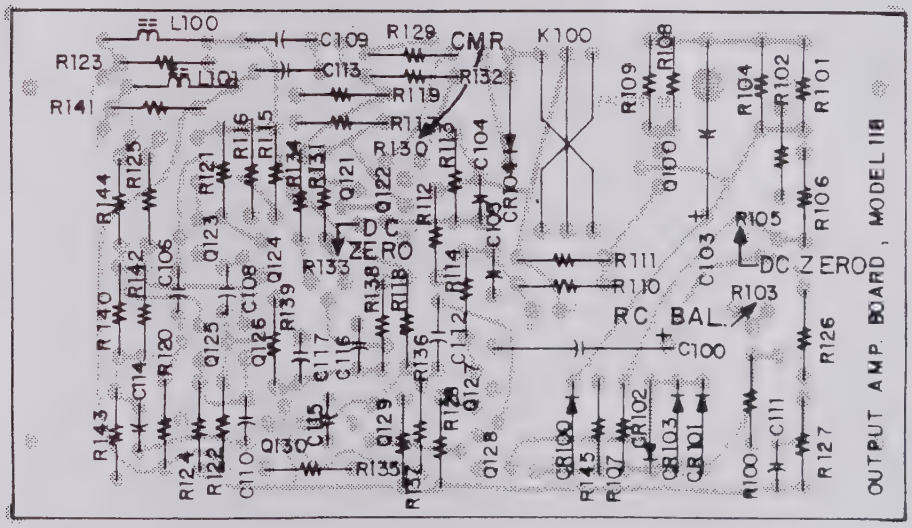
5075 D SD E



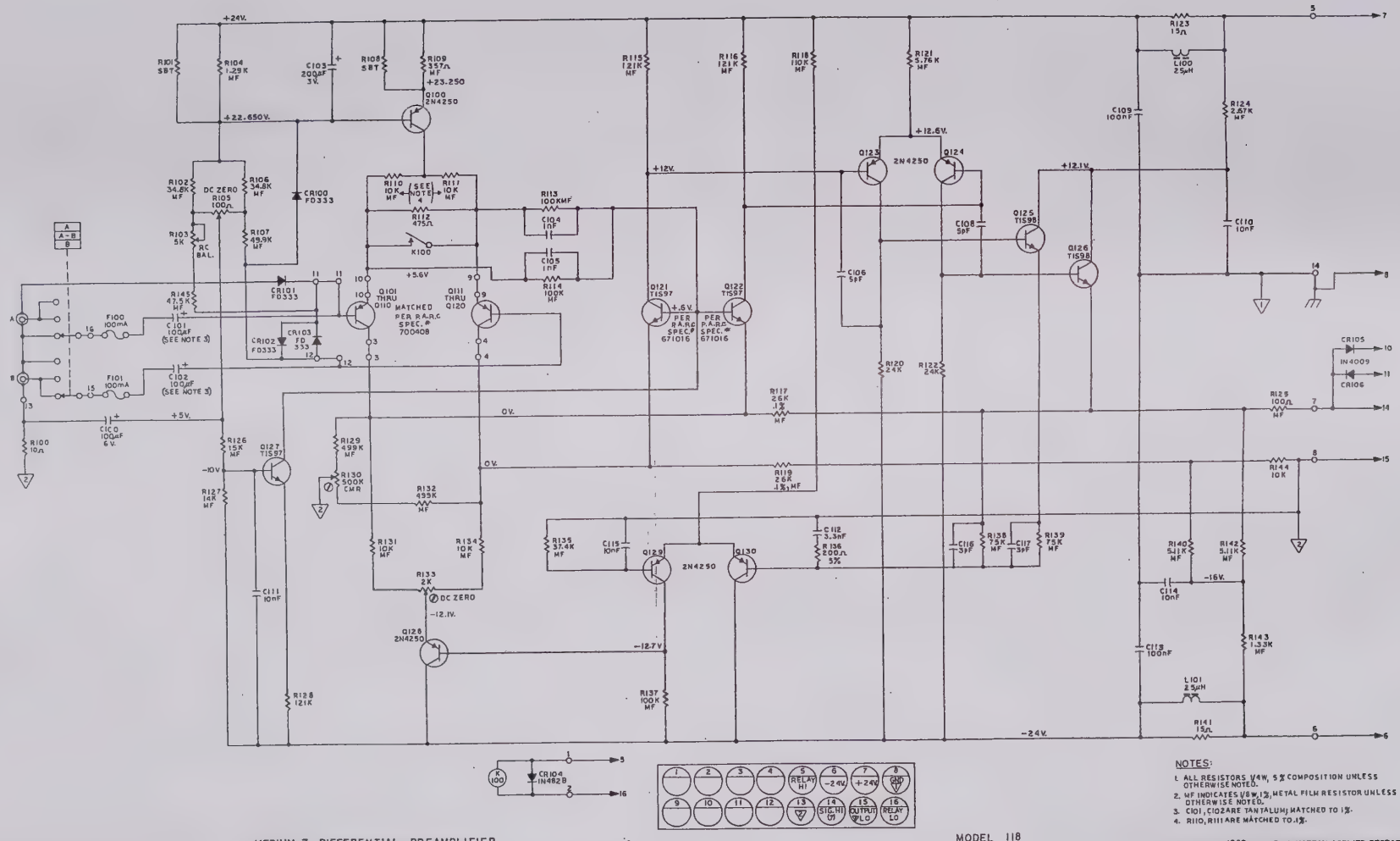
SYMBOLIZATION
MODEL 118
INPUT AMP BOARD
FAB # 5090-MD-A



SYMBOLIZATION MASTER

OUTPUT AMP. BOARD

MODEL 118



MEDIUM Z DIFFERENTIAL PREAMPLIFIER
INPUT AMP. ASSEMBLY 1180-2100-05S
(Q101 THRU Q120; C101 & C102; F100 & F101)
OUTPUT AMP. ASSEMBLY 1180-2000-06S

MODEL 118

NOTES:
1. ALL RESISTORS 1/4W, 5% COMPOSITION UNLESS OTHERWISE NOTED.
2. MF INDICATES 1/8W, 1%, METAL FILM RESISTOR UNLESS OTHERWISE NOTED.
3. C101, C102 ARE TANTALUM; MATCHED TO 1%.
4. R110, R111 ARE MATCHED TO 1%.

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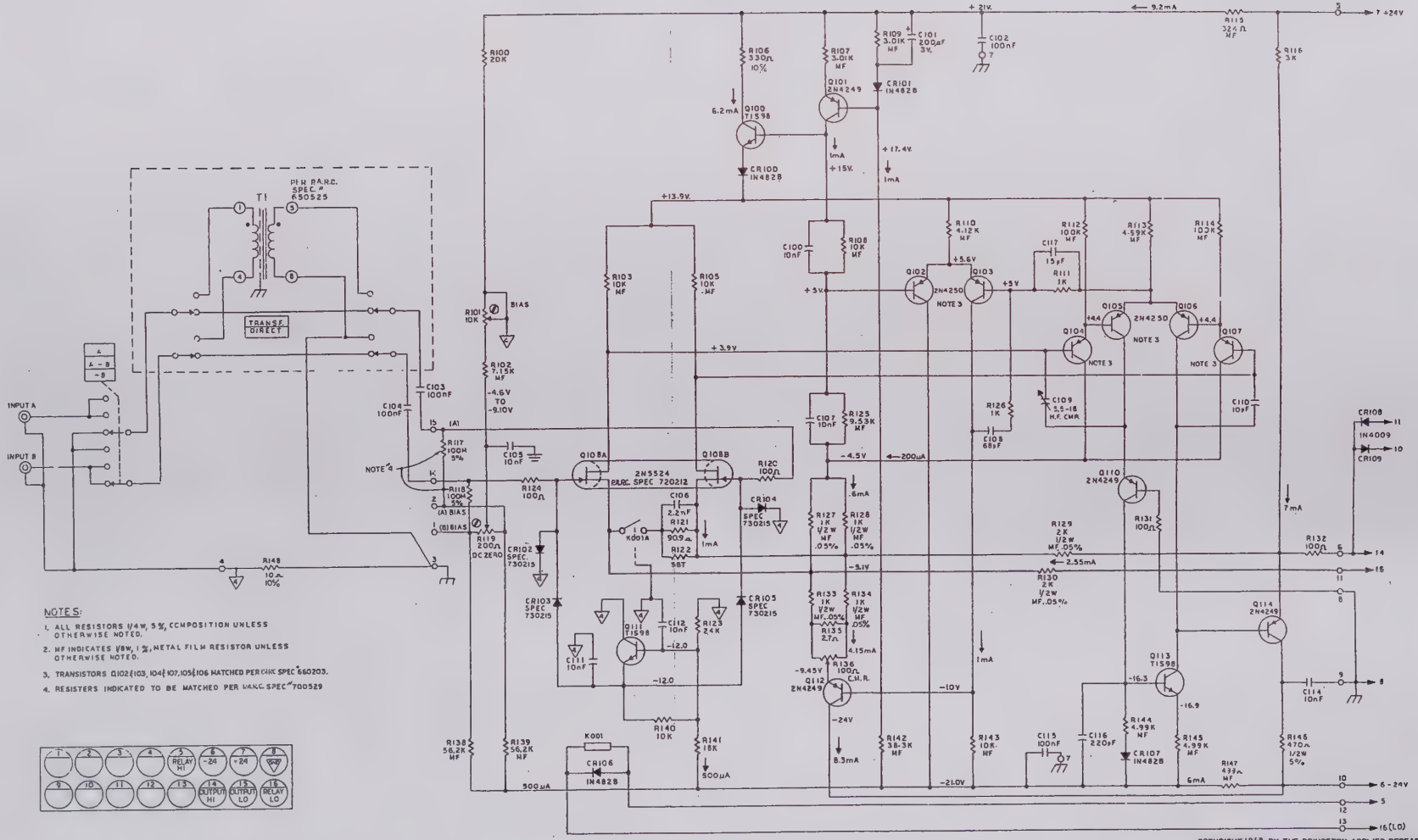
5074 D SD B



NOTES:

1. ALL RESISTORS 1/4W, 5%, COMPOSITION UNLESS OTHERWISE NOTED.
2. MF INDICATES 1/8W, 1%, METAL FILM RESISTOR UNLESS OTHERWISE NOTED.
3. TRANSISTORS Q102 & 103, 104 & 107, 105 & 106 MATCHED PER PARC SPEC 660203.
4. RESISTERS INDICATED TO BE MATCHED PER PARC SPEC 700529

DIFFERENTIAL PREAMPLIFIER
SUB ASSEMBLY 1160-2000-00s

MODEL 119

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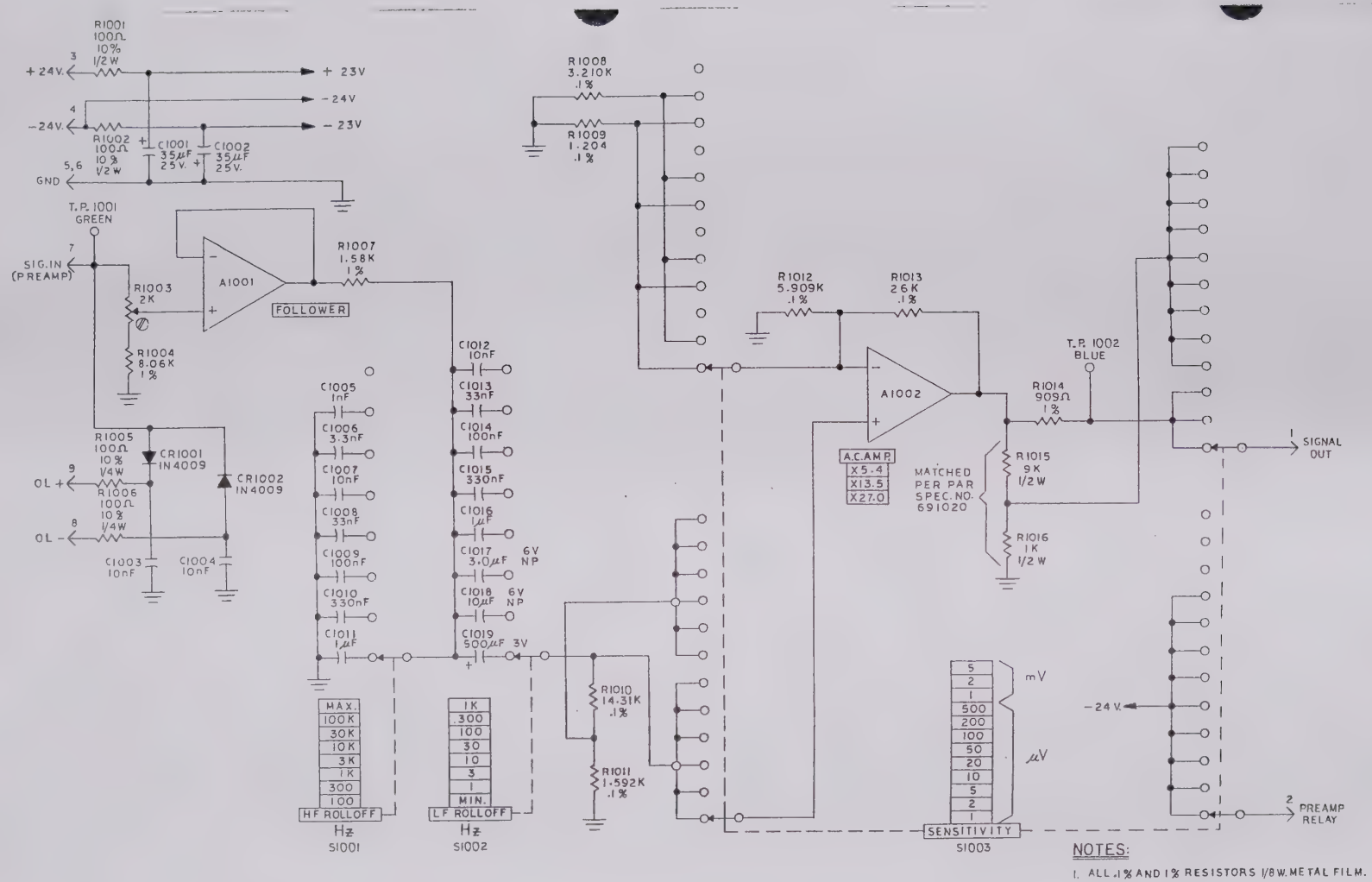
5076 D SD F



NOTES:

1. ALL .1% AND 1% RESISTORS 1/8W. METAL FILM.

SIGNAL AMPLIFIER BOARD

SUB-ASSEMBLY *1260-2200-07(PARTIAL)

MODEL 126

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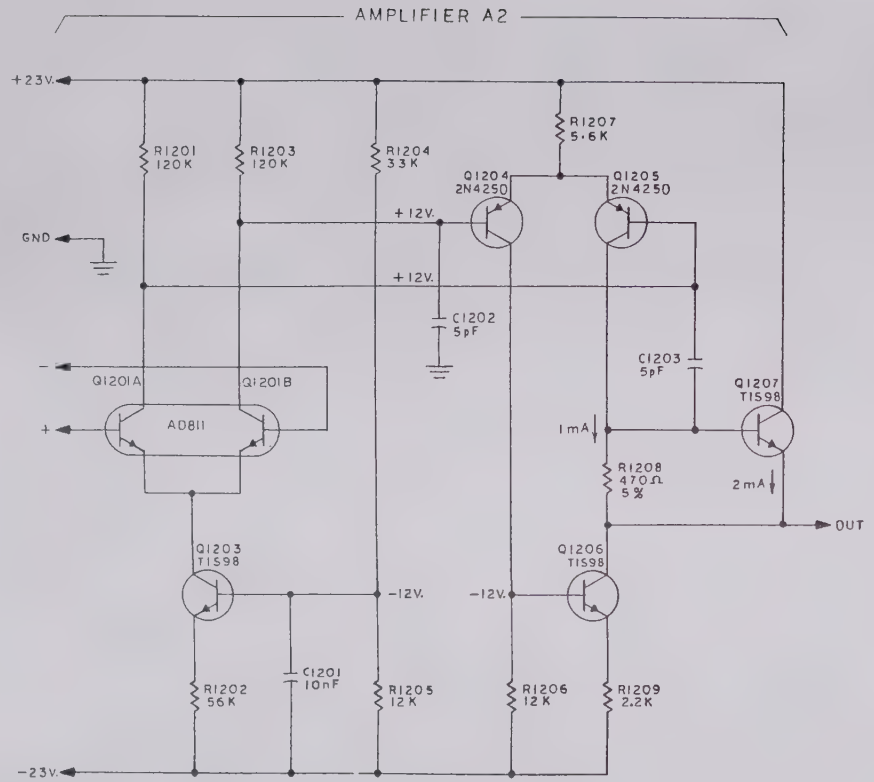
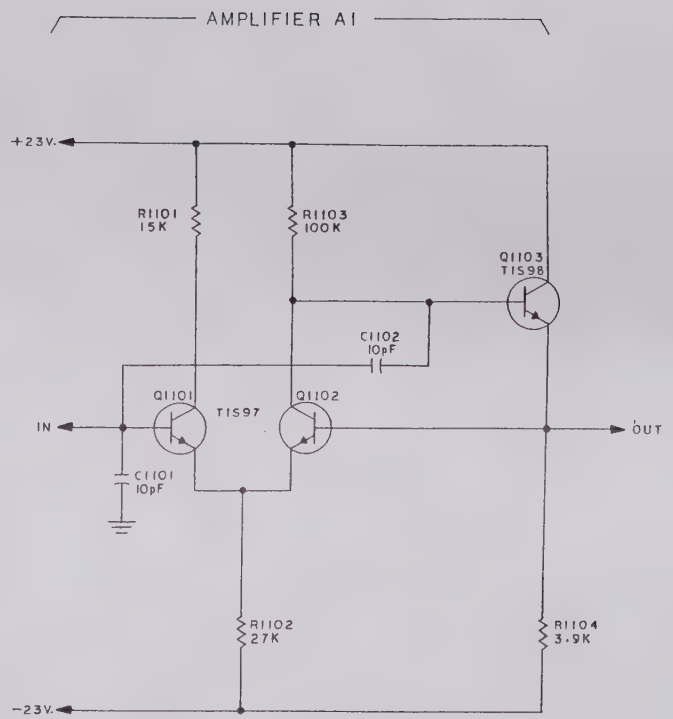
SYMBOLIZATION
MODEL 126
SIGNAL AMPLIFIER BOARD
FAB. #5910-MD-A





NOTES:

1. ALL RESISTORS 1/4W, 10%, COMPOSITION UNLESS OTHERWISE NOTED.

OPER. AMPS A1 & A2

SIGNAL AMPLIFIER BOARD

SUB-ASSEMBLY

*1260-2200-07 (PARTIAL)

MODEL 126

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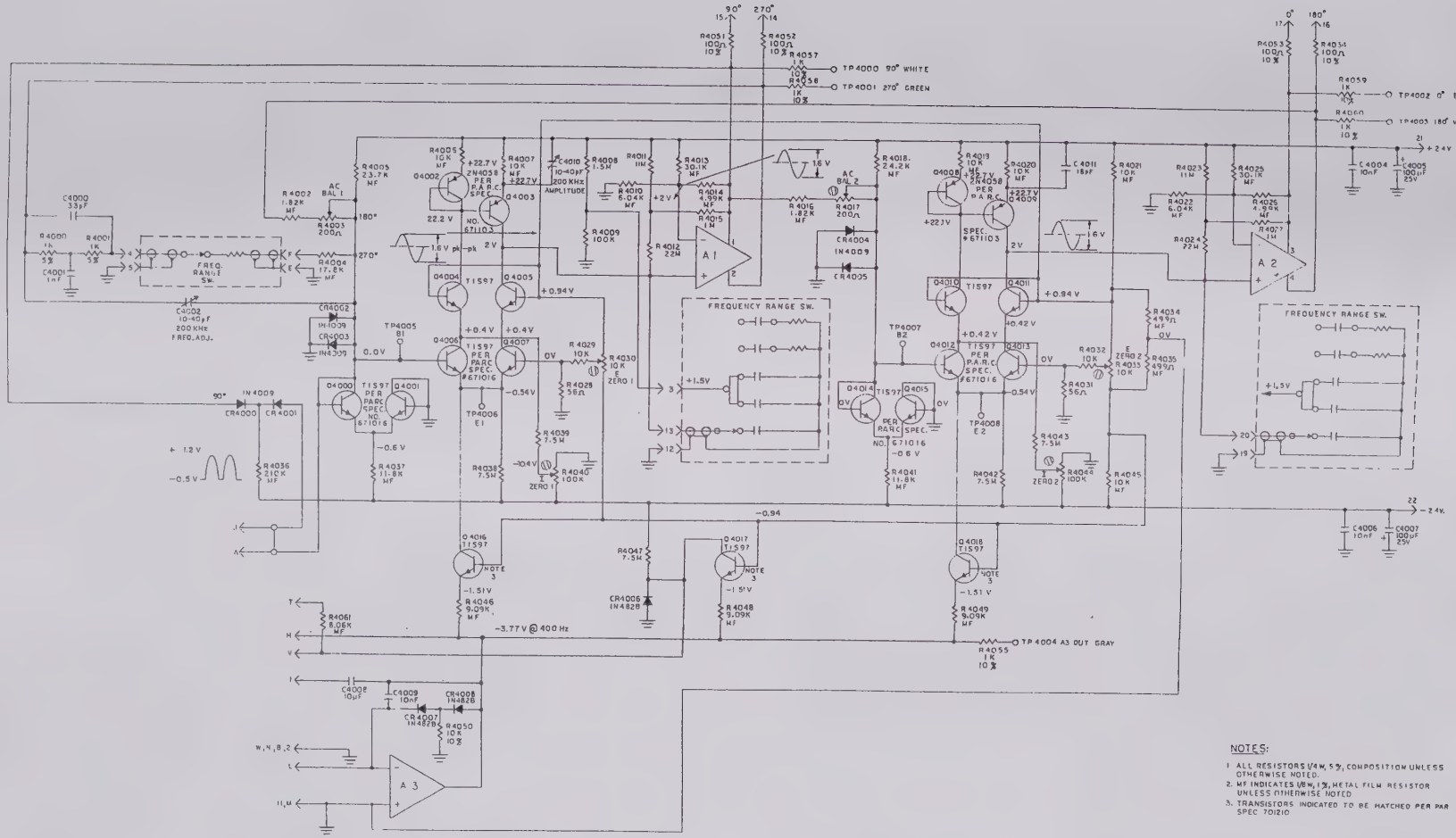
SYMBOLIZATION
MODEL 126
REFERENCE OSCILLATOR BOARD
FAB # 4980-MD-D



REFERENCE OSCILLATOR BD. MODEL 124&121A
SUB-ASSEMBLY #1240-2200-02 (PARTIAL)

NOTES:
1. ALL RESISTORS 1/4W, 5%, COMPOSITION UNLESS OTHERWISE NOTED.
2. MF INDICATES 1/8W, 1%, METAL FILM RESISTOR UNLESS OTHERWISE NOTED
3. TRANSISTORS INDICATED TO BE MATCHED PER PAR SPEC 701210

SEE 4870-D-SD FOR SHT 2 OF 3
SEE 4870-C-SD FOR SHT. 3 OF 3.

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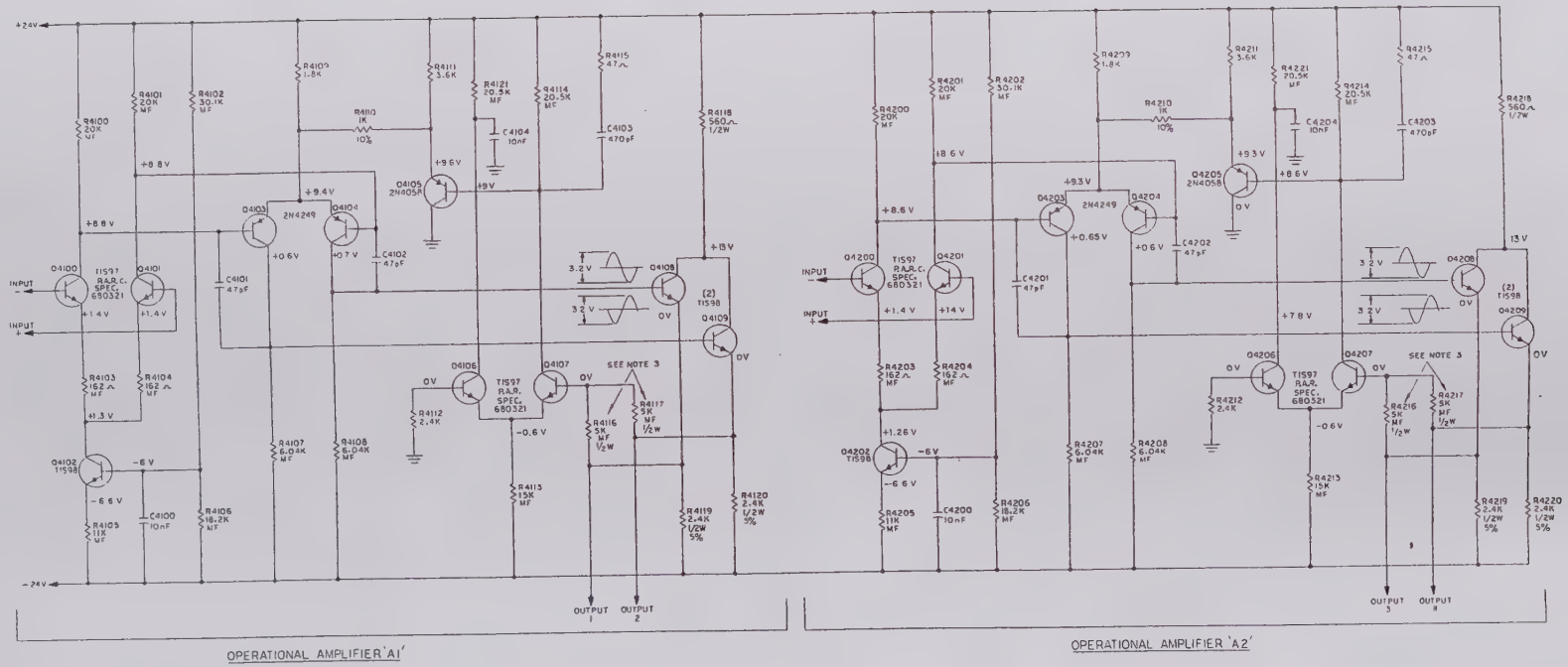
SHEET 1 OF 3 | 4870 | D | SD | F



NOTES:

1. ALL RESISTORS 1/4W, 5%, COMPOSITION UNLESS OTHERWISE NOTED.
2. MF INDICATES 1/8W, 1%, METAL FILM RESISTOR UNLESS OTHERWISE NOTED.
3. MATCHED PAIR PER SPEC #700214

REFERENCE OSCILLATOR BD. MODEL 124&124A
SUB-ASSEMBLY #1240-2200-02 (PARTIAL)

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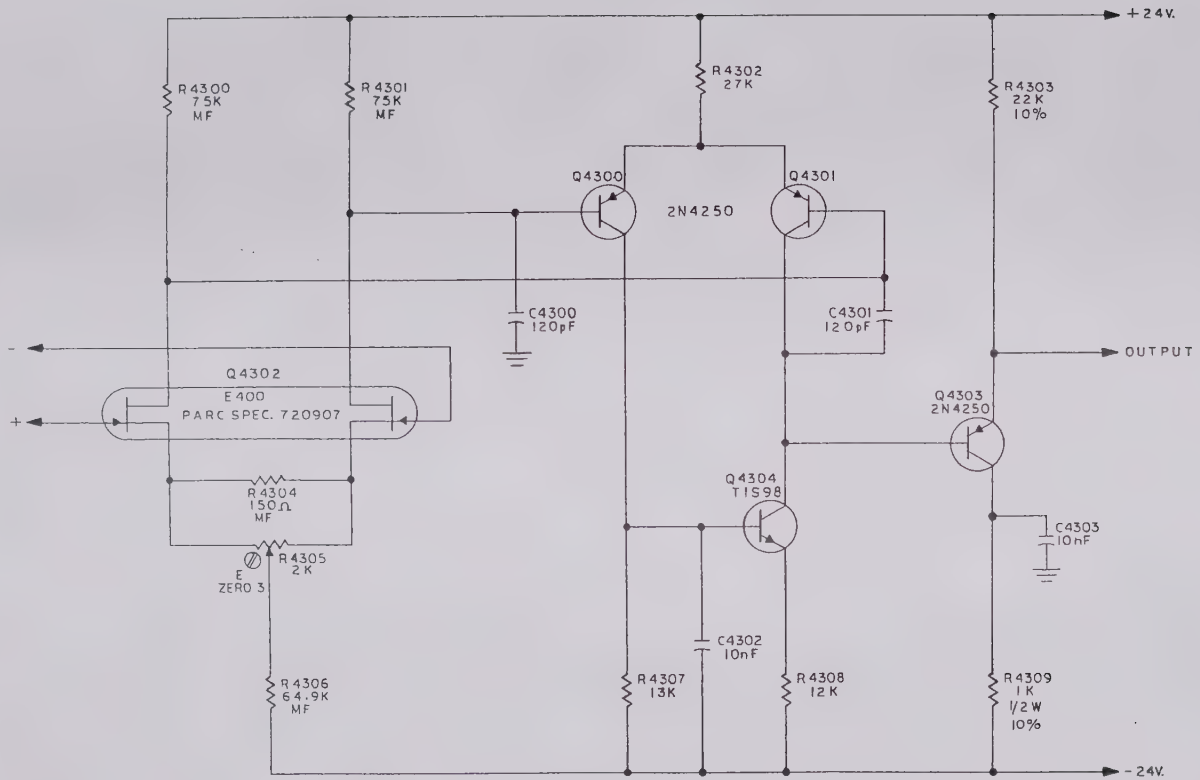

NOTES:

1. ALL RESISTORS 1/4W, 5%, COMPOSITION UNLESS OTHERWISE NOTED.
2. MF INDICATES 1/8W, 1%, METAL FILM RESISTOR UNLESS OTHERWISE NOTED.

OPERATIONAL AMPLIFIER 'A3'

REFERENCE OSCILLATOR BD.

SUB-ASSEMBLY #1240-2200-02 (PARTIAL)

MODEL 124 & 124A

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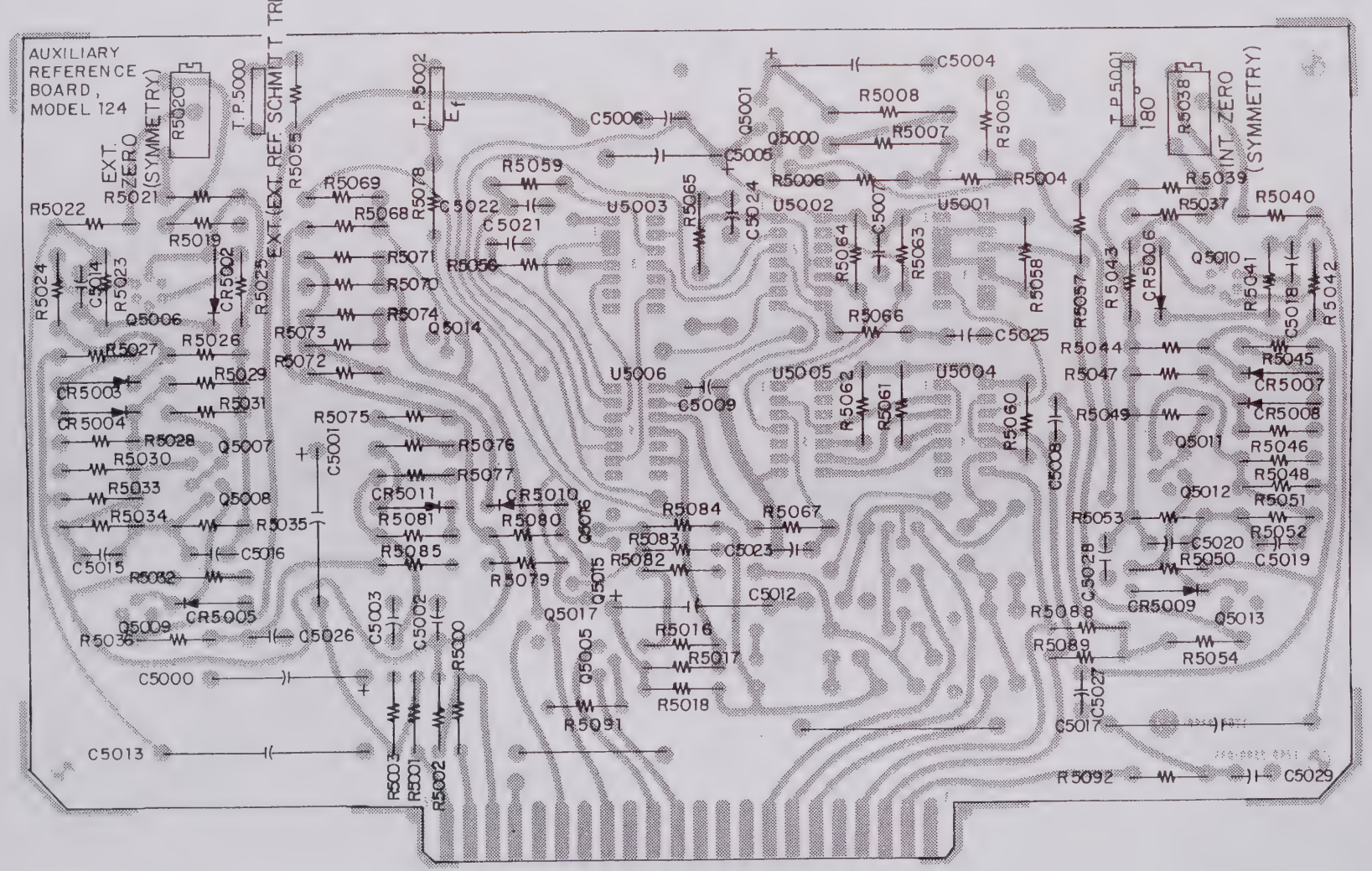
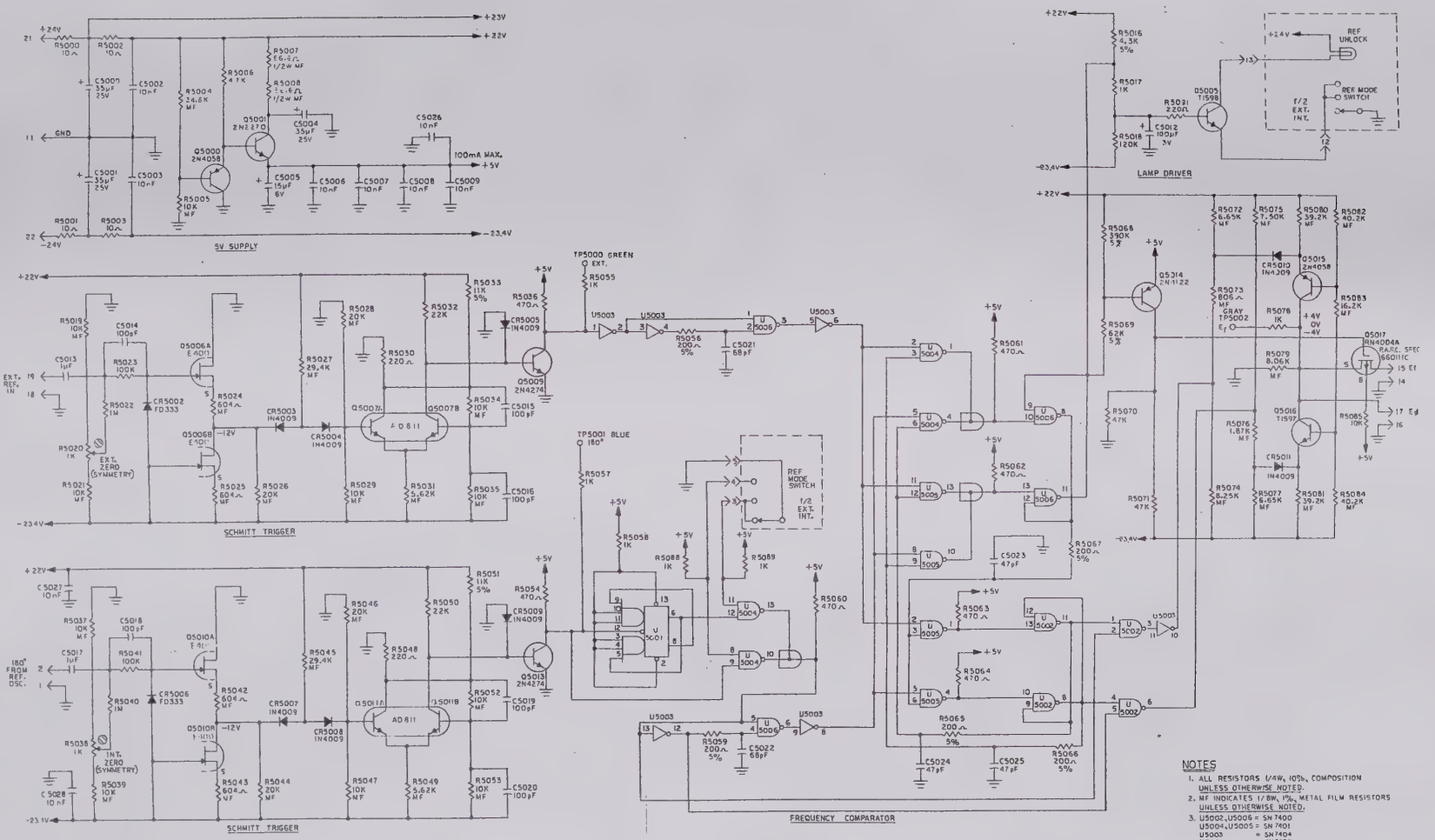


SYMBOLIZATION
MODEL 126
AUXILIARY REFERENCE BOARD
FAB. # 4983-MD-B



NOTES

1. ALL RESISTORS 1/4W, 10%, COMPOSITION UNLESS OTHERWISE NOTED.
2. MF INDICATES 1/8W, 1% METAL FILM RESISTORS UNLESS OTHERWISE NOTED.
3. U5002, U5006 = SN 7400
   U5004, U5005 = SN 7401
   U5003 = SN 7404
   U5001 = SN 7472

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
GND	180° FROM REF. OSC.	EXT. e_i	$f_i/2$	GND				GND		GND	LAMP DR. GND	LAMP DR.	GND	E_f	GND	E_g	GND	EXT. REF. IN	+23V	+24V	-24V

A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z

AUXILIARY REFERENCE BOARD MODEL 126
SUB ASSEMBLY 1260-2400-05 S

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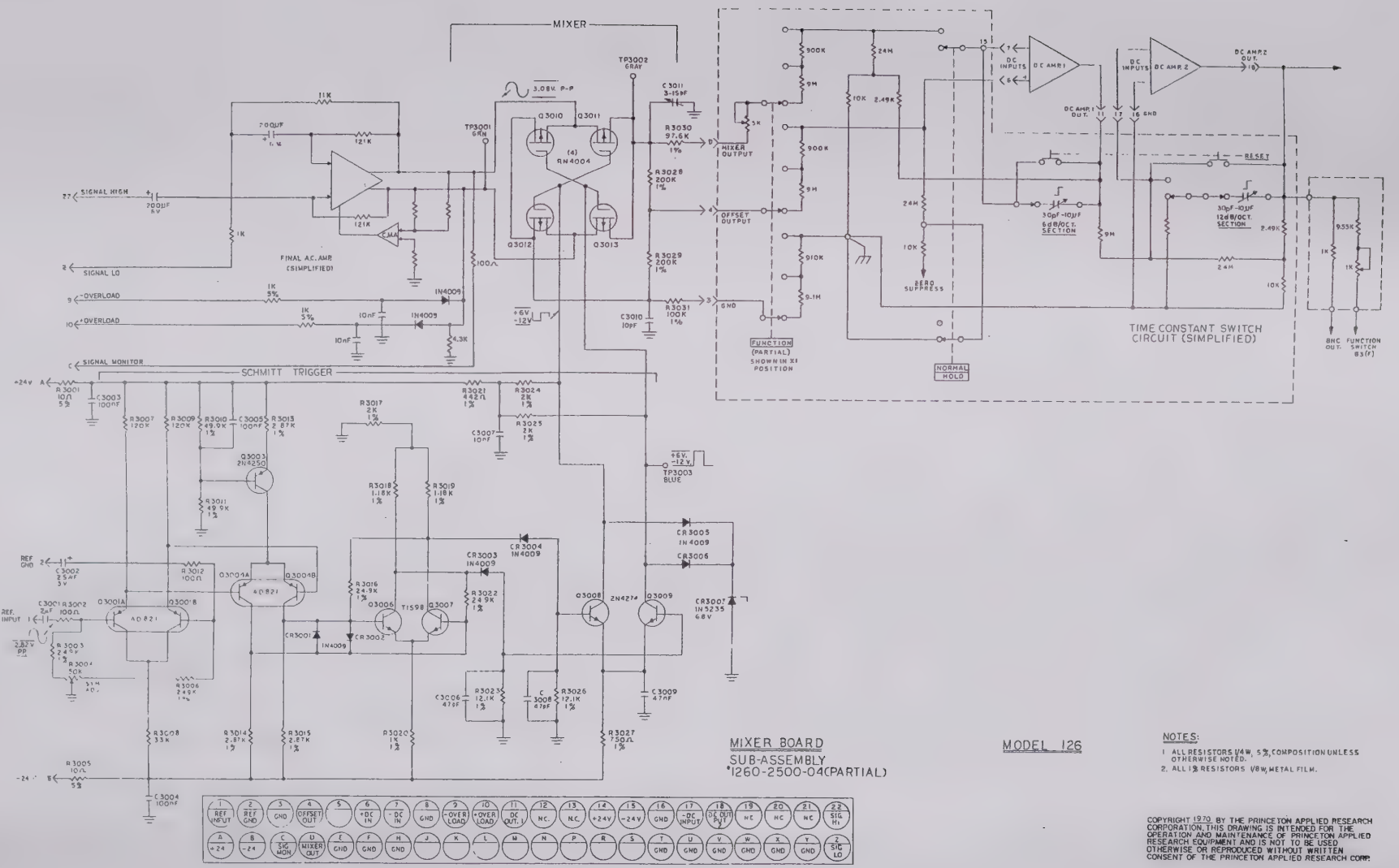
5858 D SD c

SYMBOLIZATION
MODEL 126,127
MIXER BOARD
FAB. # 5977 – MD – A



NOTES:

1. ALL RESISTORS 1/4W, 5%, COMPOSITION UNLESS OTHERWISE NOTED.
2. ALL 1% RESISTORS 1/8W, METAL FILM.

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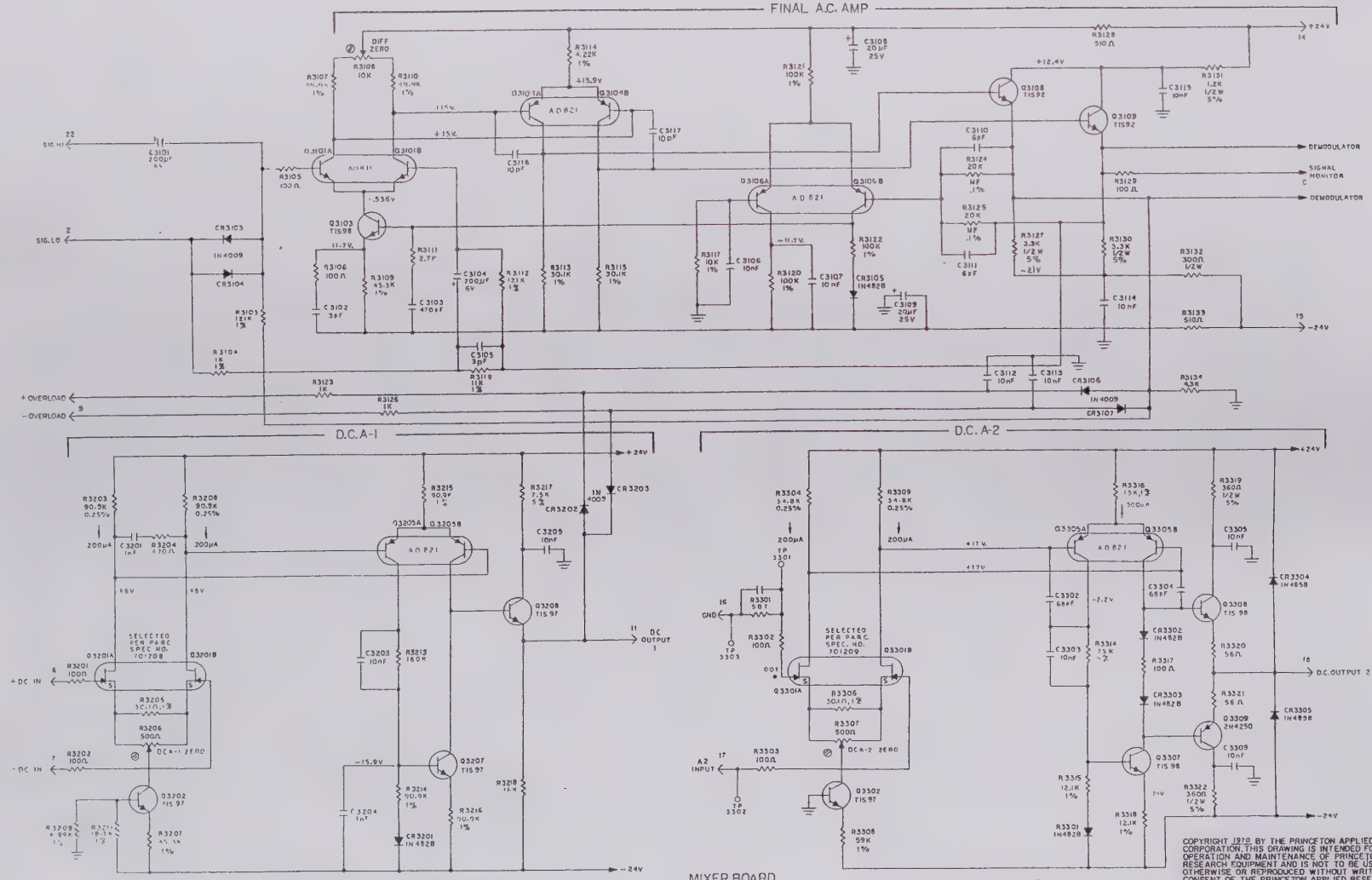

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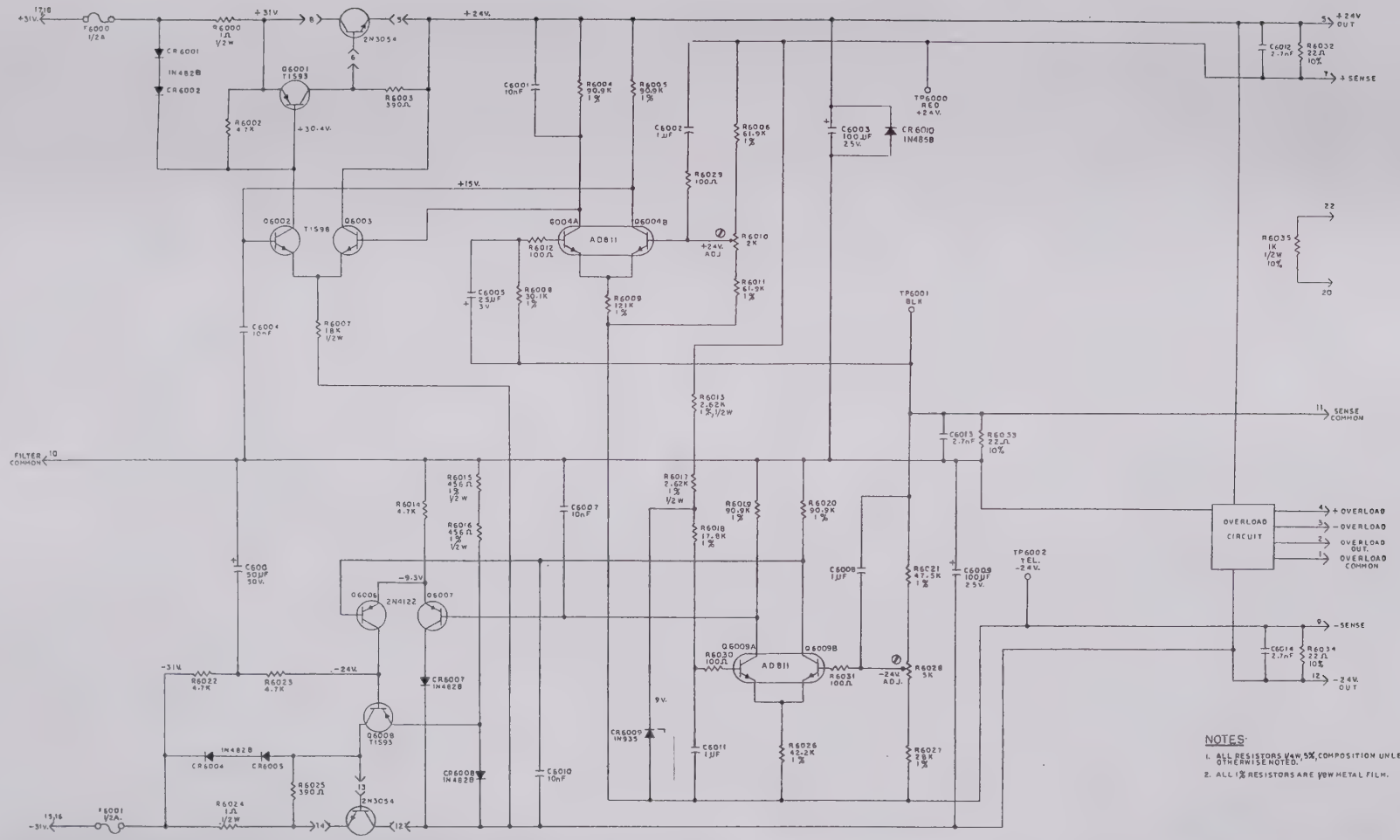

NOTES:

1. ALL RESISTORS ¼W, 5%, COMPOSITION UNLESS OTHERWISE NOTED.
2. ALL 1% RESISTORS ARE ¼W METAL FILM.

POWER SUPPLY BOARD
SUB ASSEMBLY 1260-2300-06s (PARTIAL)

MODEL 126

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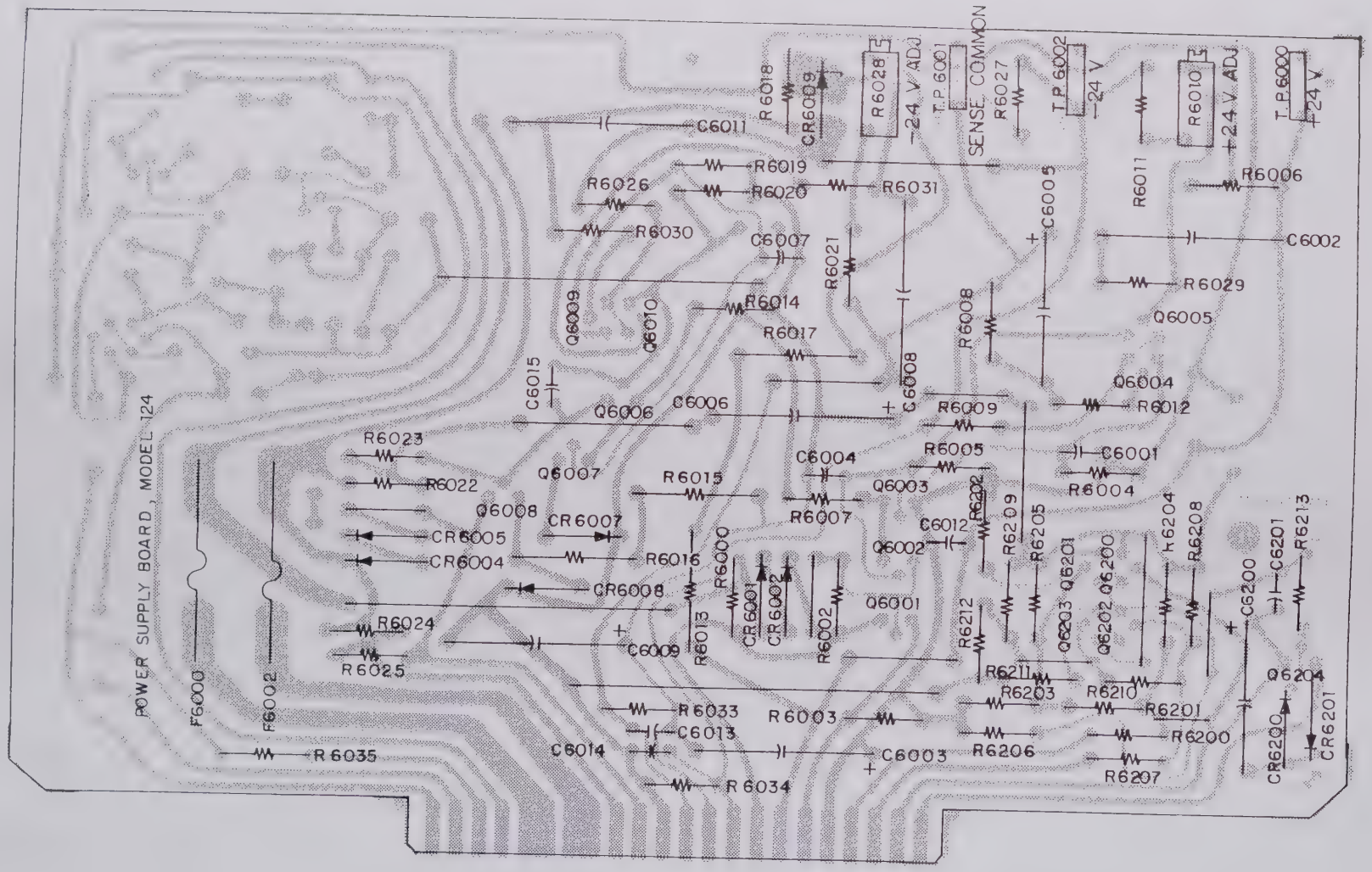
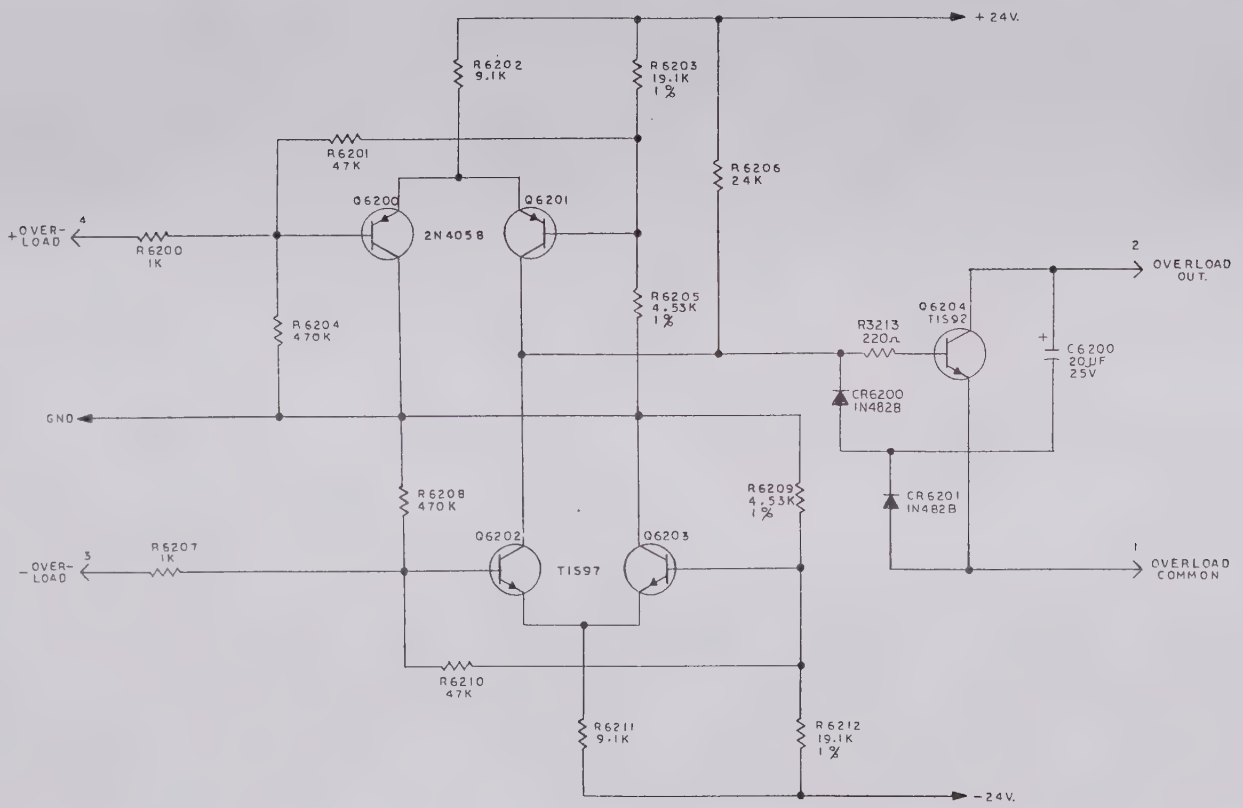
SHEET 1 OF 2 5790 D1 SOLD



SYMBOLIZATION
MODEL 126, 127
POWER SUPPLY BOARD
FAB. # 4986 - MD - A

OVERLOAD CIRCUIT



POWER SUPPLY BOARD
SUB ASSEMBLY 1260-2300-06s (PARTIAL)

MODEL 126

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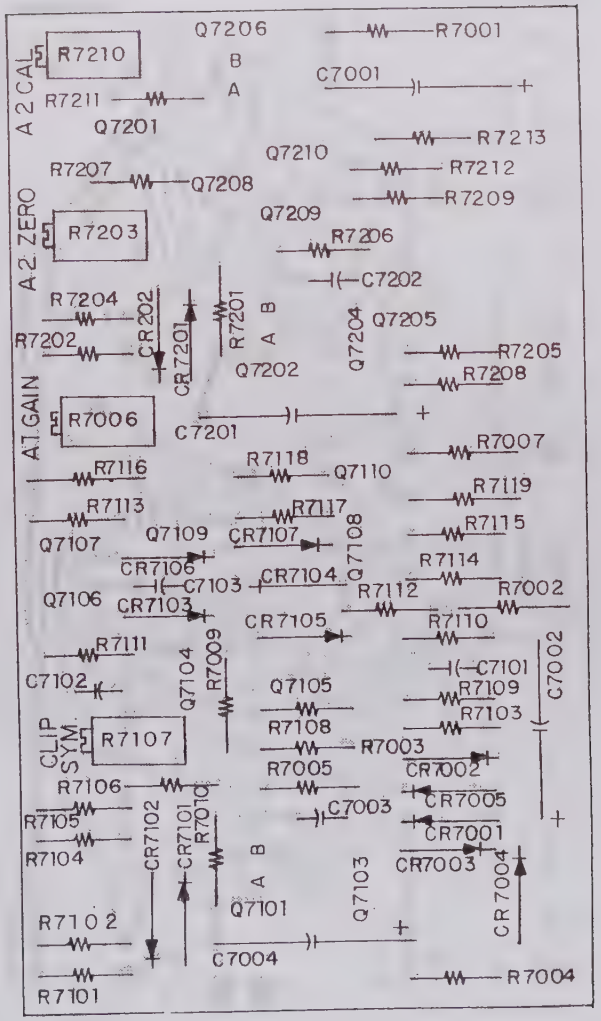
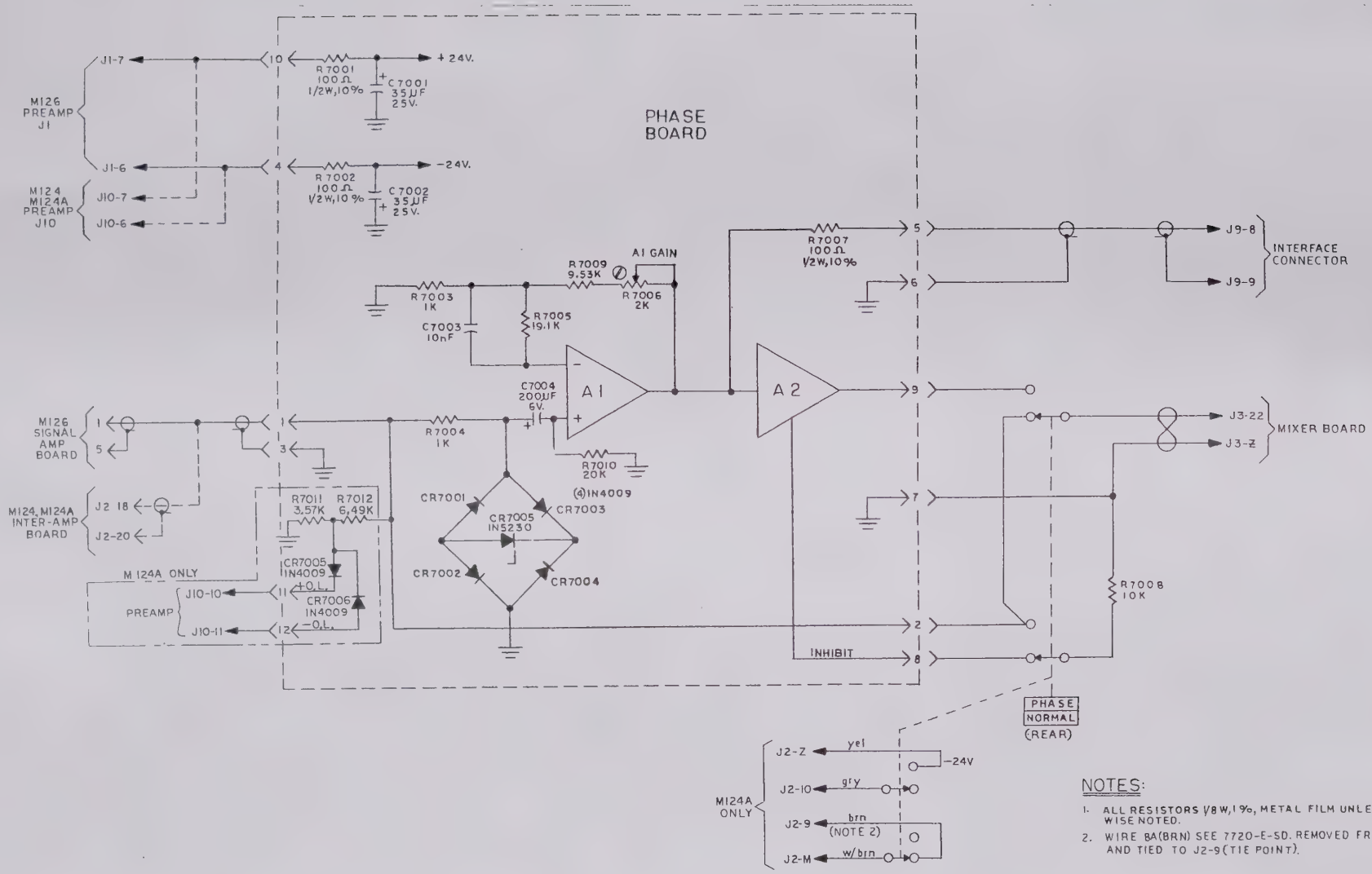


SYMBOLIZATION
MODEL 126,124A
PHASE METER OPTION BOARD
FAB.# 6105-MD-B



NOTES:

1. ALL RESISTORS 1/8 W, 1%, METAL FILM UNLESS OTHERWISE NOTED.
2. WIRE 8A(BRN) SEE 7720-E-SD. REMOVED FROM J2-M AND TIED TO J2-9 (TIE POINT).

PHASE METER MODIFICATION
126/99, 1240/85, 1241/85

MODEL 126
124, 124A

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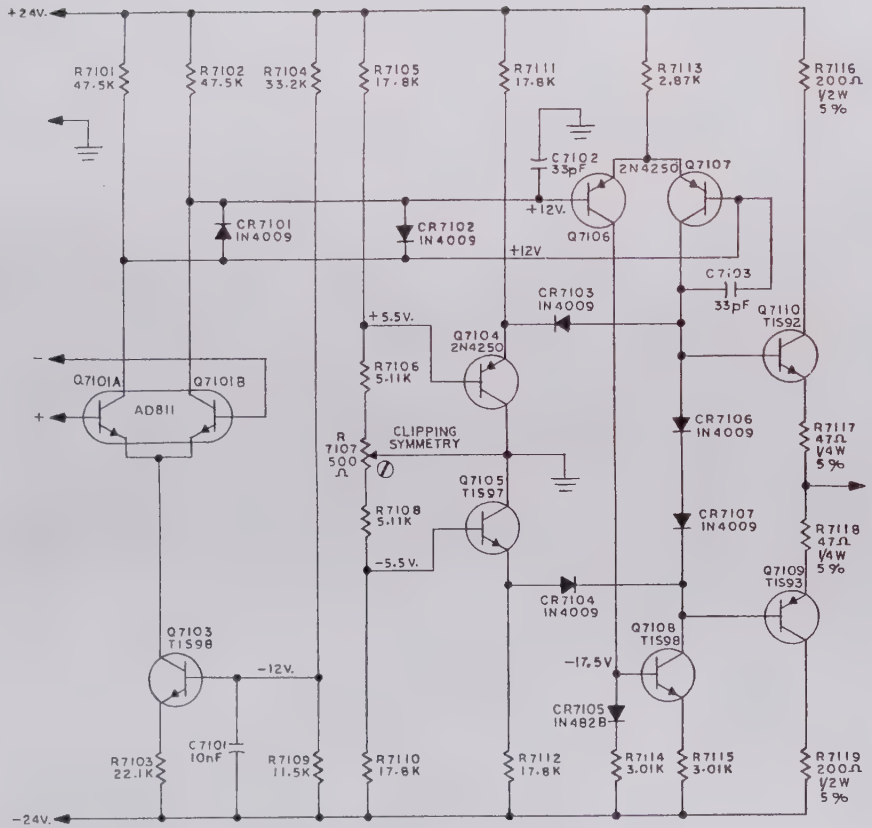
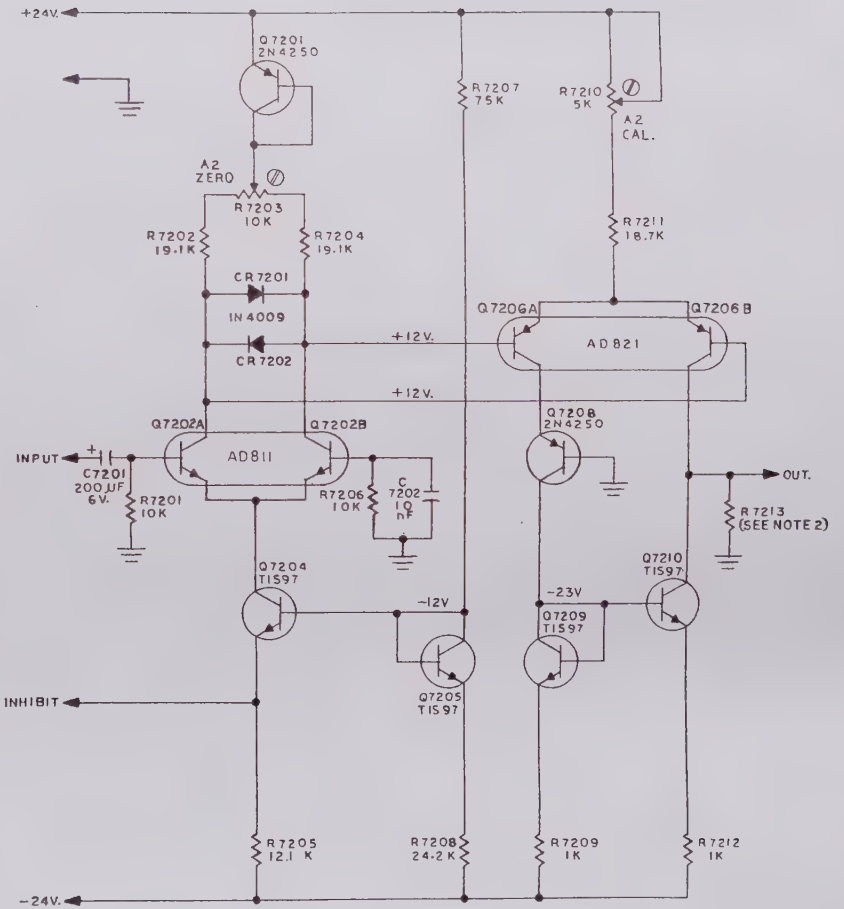
OP. AMP.



AMP. LIMITER



NOTES:

1. ALL RESISTORS 1/8W, 1%, METAL FILM UNLESS OTHERWISE NOTED.
2. MODEL 126 = 15Ω
   MODEL 124 = 150Ω
   MODEL 124A = 75Ω

AMPLIFIERS

MODEL 126, 124, 124A

PHASE METER MODIFICATION
1260/99, 1240/85, 1241/85

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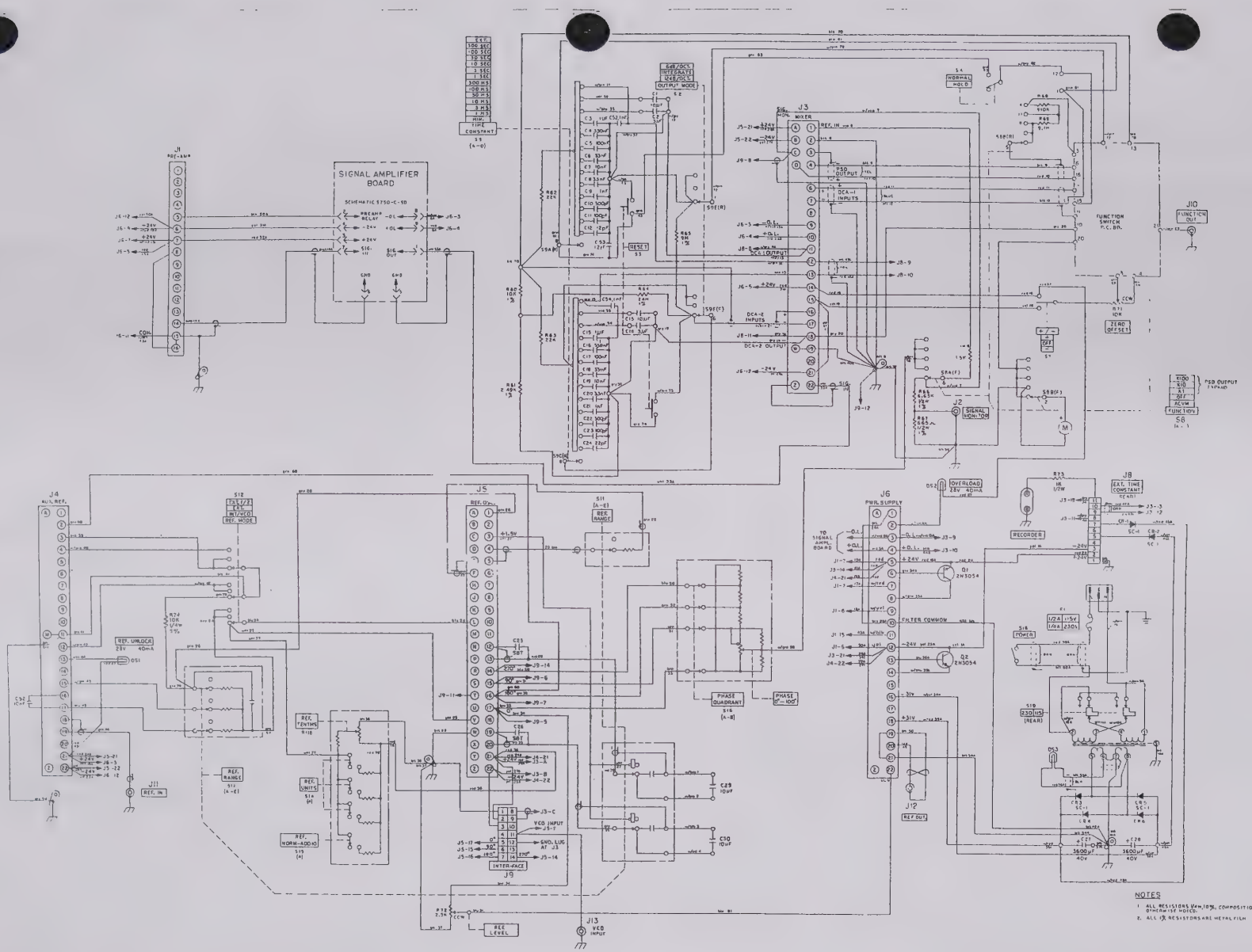

CHASSIS WIRING SCHEMATIC MODEL 126

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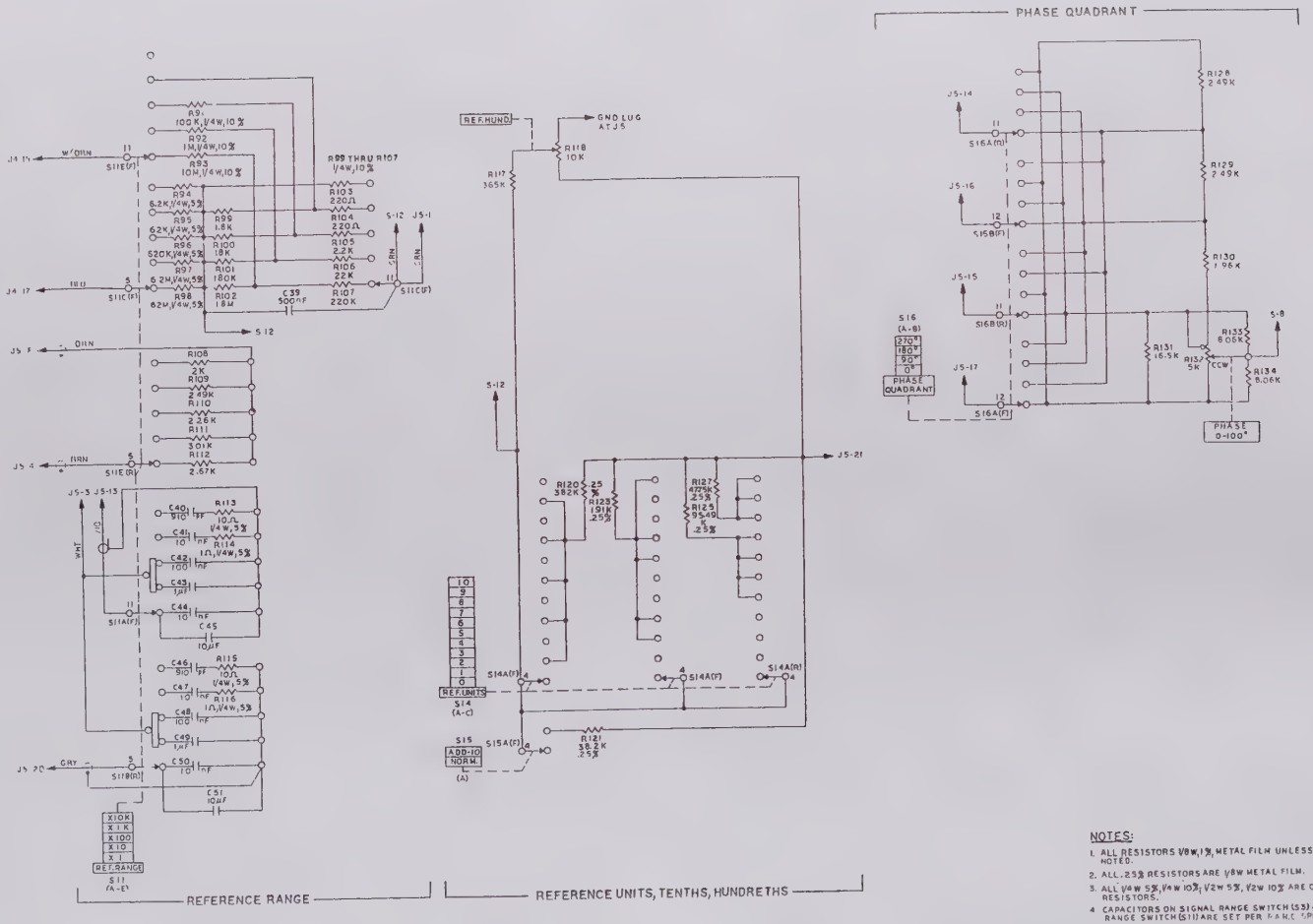
SHEET 1 OF 3 5808 E SD C



SWITCH SCHEMATIC

MODEL 126

NOTES:

1. ALL RESISTORS 1/8W, 1%, METAL FILM UNLESS OTHERWISE NOTED.
2. ALL .25% RESISTORS ARE 1/8W METAL FILM.
3. ALL 1/4W 5%, 1/4W 10%, 1/2W 5%, 1/2W 10% ARE COMPOSITION RESISTORS.
4. CAPACITORS ON SIGNAL RANGE SWITCH (S3) AND REFERENCE RANGE SWITCH (S11) ARE SET PER P.A.R.C. SPEC #10012
5. R76 THRU R90 ARE .1%, 1/2W, METAL FILM.

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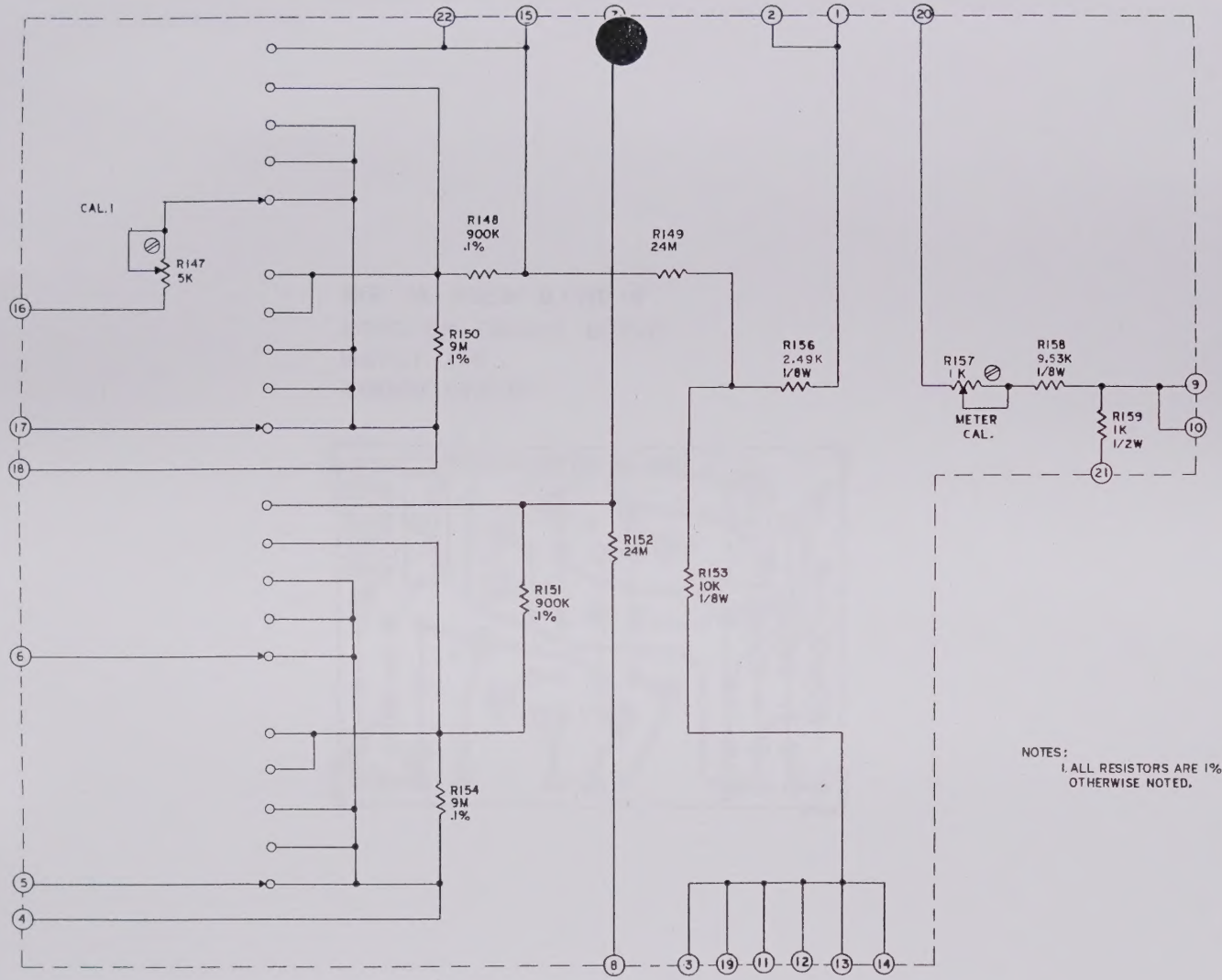

NOTES:
1. ALL RESISTORS ARE 1% METAL FILM UNLESS OTHERWISE NOTED.

FUNCTION SWITCH BD.
SUB-ASSEMBLY
*1260-2700-02S

MODEL 126

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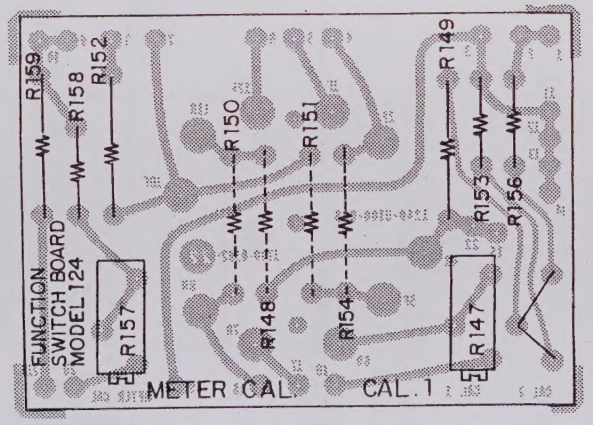

SYMBOLIZATION
MODEL 126
FUNCTION SWITCH BOARD
FAB. # 5229-B-MD-B

MP MASTER

MA22494

EG&G
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